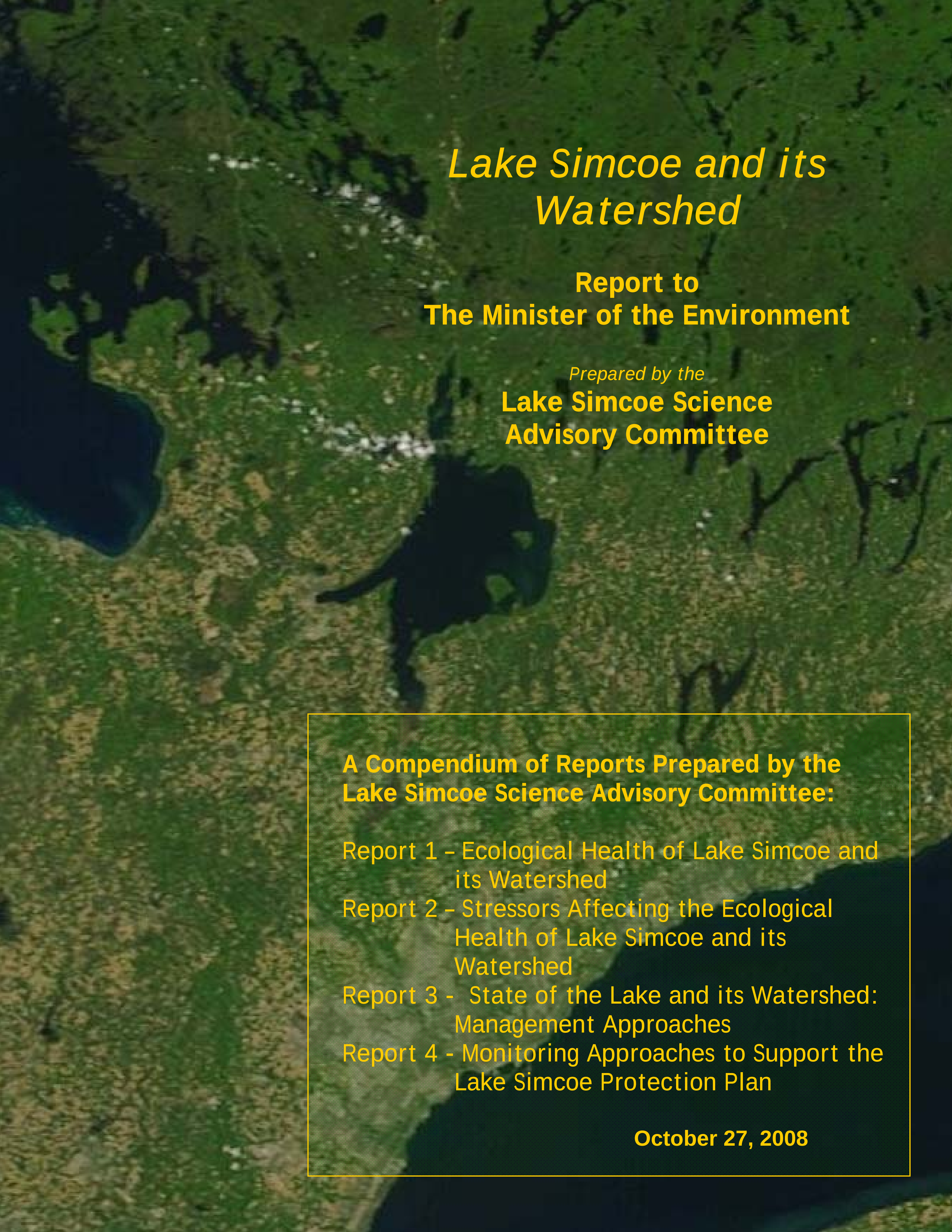


Lake Simcoe and its Watershed

Report to
The Minister of the Environment

Prepared by the

Lake Simcoe Science Advisory Committee

A Compendium of Reports Prepared by the Lake Simcoe Science Advisory Committee:

Report 1 – Ecological Health of Lake Simcoe and its Watershed
Report 2 – Stressors Affecting the Ecological Health of Lake Simcoe and its Watershed
Report 3 - State of the Lake and its Watershed: Management Approaches
Report 4 - Monitoring Approaches to Support the Lake Simcoe Protection Plan

October 27, 2008

Acknowledgements

We are grateful for the contribution and support received from the Technical Team members, and managers and staff from the Lake Simcoe Region Conservation Authority, the Ministry of Aboriginal Affairs, Ministry of Agriculture, Food and Rural Affairs, Ministry of the Environment, Ministry of Municipal Affairs and Housing, Ministry of Natural Resources, Ministry of Public Infrastructure Renewal, the Stakeholder Advisory Committee, French Planning Services Inc., and other individuals in assisting us in preparing this report.

A special thank-you is extending to the Honourable John Gerretsen Minister of the Environment and Michael Williams, the Assistant Deputy Minister (ADM) for graciously attending our meetings and providing words of encouragement and support for this scientific endeavour and the protection of Lake Simcoe, its watershed and community.

Science Advisory Committee:

SciAC Co-chairs

Dr. Peter Dillon, Co-chair, Professor, Environmental Resource Study Program and Director of the Water Quality Centre at Trent University

Dr. Jenny Winter, Co-chair, Research Scientist, Ministry of the Environment

SciAC Members

Dr. David Barton, Professor, University of Waterloo

Dr. David Evans, Senior Research Scientist, Ministry of Natural Resources and Adjunct Professor, Trent University

Dr. Bahram Gharabaghi, Professor, Engineering Department, University of Guelph

Dr. Stephanie Guildford, Professor, University of Minnesota

Dr. John Gunn, Professor, Laurentian University

Dr. Lewis Molot, Professor, York University

Dr. Ivan O'Halloran, Professor, Ridgetown Campus, University of Guelph

Dr. Justina Ray, Executive Director, Wildlife Conservation Society Canada and Adjunct Professor, University of Toronto and Trent University

Dr. Cynthia Wesley-Esquimaux, Professor, Aboriginal Studies, University of Toronto

Rhonda Gagnon, Water Resources Policy Analyst, Lands and Resources Department, Union of Ontario Indians

Photos Provided by:

Lake Simcoe Region Conservation Authority
Ministry of the Environment
Lake Simcoe Fisheries Assessment Unit
Ministry of Natural Resources
French Planning Services Inc.

Cover Photo taken on May 28, 2008 at 1540 hrs:

Great Lakes CoastWatch Node
NOAA/Great Lakes Environmental Research Laboratory
2205 Commonwealth Blvd.
Ann Arbor, MI 48105-2945
http://coastwatch.glerl.noaa.gov

Facilitation Services provided by:
French Planning Services Inc.
www.frenchplanning.com
www.lakeplan.com

Table of Contents

Maps

Tables

Figures

Introduction

The Science Advisory Committee

The four objectives of the Lake Simcoe Science Advisory Committee are to: 1) evaluate the present state of the lake and its watershed, 2) identify current and emerging pressures (stressors) on the lake and its watershed, 3) advise the Provincial government on management approaches to mitigate the impact of these stressors and 4) propose a refined or enhanced monitoring framework to support the proposed Lake Simcoe Protection Plan.

> **Sustainability…**
>
> *"…meet the needs of the present without compromising the ability of future generations to meet their own needs."*

In effect, the Committee has been charged with proposing ways of ensuring that human activities (i.e. development) in the watershed are environmentally 'sustainable'. So what does sustainable development mean? The most common definition is the one used by the Brundtland Commission two decades ago as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987, "Report of the World Commission on Environment and Development" General Assembly Resolution 42/187, 11 December 1987). Development is used here in a broad economic sense to include major human activities such as agriculture, fishing, horticulture, forestry, mining, tourism, manufacturing and urban development. In the discussion that follows, 'development' includes existing and future activities and refers to more than just urban development and the building of associated infrastructure.

The Brundtland definition is an important one but provides little in the way of specific options for managing a large lake and its watershed. Fortunately, in the last three decades many jurisdictions including the Ontario government have developed lake and watershed management approaches that have successfully permitted development to occur (but not necessarily unrestricted development) without unduly impairing the ecological health of a watershed and lake. 'Unduly' means that government must ultimately decide on the maximum amount of damage that can be inflicted on the natural system in question based on relevant scientific information. Of course, there are many ways of inflicting damage on a complex ecosystem like Lake Simcoe. Some of these stresses originate locally such as excessive inputs of phosphorus and other chemicals while others such as climate change have a more global origin and still others such as invading species fall in between these two extremes.

A successful management approach starts with a scientific evaluation of the system, in order to determine the extent of the damage that has occurred and the root causes. It then proceeds with an assessment to determine whether serious, unacceptable environmental damages have already occurred based on considerations of human and environmental health criteria. More challenging but equally important is the task of determining the upper limits to such damages that the ecosystem can tolerate without incurring excessive harm. Management recommendations are then made based on these scientific evaluations with the aim of avoiding further damage and/or repairing damage from past neglect. The four reports prepared by the Lake Simcoe Science Advisory Committee are based on a series of twelve questions that closely follow this approach.

As you read these reports, you will undoubtedly be aware of how complex environmental processes and biological communities are. Nevertheless, scientists are often able to identify a small number of scientific variables (things that scientists measure) that are very important, easy to understand and help simplify large amounts of complex information. These are called environmental indicators. For example, dissolved oxygen and phosphorus concentrations are often used as indicators of a lake's health. Scientists know enough about these two indicators to be able to predict, for example, when they may cause lake trout populations to decline or collapse. Hence, indicators are often used to characterize and communicate the condition of a lake to the public.

Successful Management Involves…

- *Scientific evaluation*
- *Assessment of damage*
- *Tolerable limits defined*
- *Strategies to repair or avoid further damage*
- *Monitoring to track changes and modify management approaches*

Finally, some environmental indicators can be compared to legal standards (or guidelines) to determine if environmental quality is 'good' or 'bad' and can then be used to guide management actions to ensure that these indicators remain on the 'good' side rather than the 'bad' side of environmental health. Measures of indicators collected over time (trends) can also be used to determine if the health of the environment is improving or worsening. It should be noted, however, that many indicators are more elusive in nature. For example, determining how much habitat is enough (or conversely, how much habitat loss is too much) to ensure persistence of wildlife and fish populations is dependent on the species and ecological context. It is for precisely this reason that we are urging an adaptive management approach where we learn from applying specific management actions and observing how the system responds, i.e. we learn and adapt based on our experience. This would take place through continued monitoring of Lake Simcoe and its watershed to ensure that its environmental state can be tracked in a timely fashion and that management approaches can be modified as needed to ensure continued benefits from a healthy ecosystem.

The Reports

The four objectives of the Lake Simcoe Science Advisory Committee have been addressed by answering twelve key questions and presenting their information and recommendations into the following four reports.

Report 1 – Ecological Health of Lake Simcoe and its Watershed

Q. 1 – What are the key attributes of the lake and its watershed that need to be considered when assessing the lake's ecological health?

Q. 2 – What are the key indicators of these attributes that we can quantify and measure?

Q. 3 – From an ecological perspective, how can the current state of Lake Simcoe and its watershed be described?

Q. 4 – What is the potential for recovery and restoration of this ecosystem?

Report 2 – Stressors Affecting the Ecological Health of Lake Simcoe and its watershed

Q. 5 – What are the key current and future threats to the ecological health of the lake and its watershed?

Q. 6 – To what extent does the health of Lake Simcoe depend on activities on the surrounding terrestrial landscape?

Q. 7 – To what extent does the health of Lake Simcoe depend on control of sources of pollution beyond its watershed boundary (e.g., atmospheric loading of P)?

Report 3 – State of the Lake: Management Responses

Q. 8 – What are the major requirements for restoration of a naturally sustaining cold-water fish community in Lake Simcoe?

Q. 9 - What are the necessary spatial boundaries for the sustainable management of Lake Simcoe?

Q. 10 - What approaches are required to mitigate the impact of the multiple stressors acting on Lake Simcoe?

Q. 11 – Is it necessary to identify areas of special concern for restoration and protection within the lake and its watershed (such as nearshore areas, bays, sub-watersheds, certain terrestrial features, riparian areas, wetlands, or headwater streams)?

Report 4 – Monitoring Approaches to Support the Lake Simcoe Protection Plan

Q. 12 – What approach should be used to establish and maintain up-to-date objectives and targets for the lake and its watershed to support the proposed Lake Simcoe Protection Plan?

The Honourable John Gerretsen addressing the Members of the Science Advisory Committee

REPORT 1 SUMMARY: Ecological Health

The Lake Simcoe Science Advisory Committee was appointed in March 2008 to advise the Government of Ontario on how best to protect and improve the Lake Simcoe ecosystem. Specifically, the committee was asked by the government to use its expertise and its knowledge of current Lake Simcoe science to:

- evaluate the present state of the lake and its watershed;
- identify current and emerging pressures (stressors) on the lake and its watershed;
- advise on management approaches to mitigate the impact of these stressors; and
- propose a refined or enhanced monitoring framework to support the Lake Simcoe protection plan.

The Committee was asked to answer a series of questions on these topics. This report covers the Committee's findings related to its examination of the ecological health of Lake Simcoe and its watershed with respect to five of those questions.

1. What are the key attributes of the lake and its watershed that need to be considered when assessing the lake's ecological health?

The Committee started by defining a ``healthy ecosystem`` as one whose current condition is comparable to historical conditions or to similar healthy ecosystems that have not been degraded by human activities. It identified five key components that must be addressed when considering the ecological health of Lake Simcoe and its watershed:

1. Physical components such as lake and river/stream shape, hydrology (water movement between atmosphere, watershed and lake), light regime, temperature regime, and water movements.
2. Chemical components and processes in the lake and watershed, for example, excessive levels of the essential plant macronutrients nitrogen and phosphorus in surface waters often results in excessive plant and algal growth in the water body.
3. Biotic components and processes, the distribution, growth dynamics and interaction of organisms.
4. Terrestrial (watershed) components and processes including geology, physiography, vegetation, soil and land use.
5. Regional (airshed) components including climate and atmospheric transport of materials that affect the physical, chemical and biological components of the lake and its watershed.

2. What are the key indicators of these attributes that we can quantify and measure?

The Science Advisory Committee identified a range of indicators that can be used as criteria to monitor the health of Lake Simcoe in the five key components: physical, chemical, biological, terrestrial (watershed), regional (airshed).

The Committee provided further advice on how these indicators could be adapted to the specific characteristics of Lake Simcoe. For example, indicators in the biological category include species richness, abundance and spatial distribution of species. These are essential indicators for tracking success in achieving the objectives of protecting the natural biodiversity of the lake and watershed and maintaining a self sustaining cold water fish community.

3. From an ecological perspective, how can the current state of Lake Simcoe and its watershed be described?

Water quality problems in Lake Simcoe have been documented since the 1970s and remain a cause for considerable concern. Problems include an estimated three-fold increase in phosphorus (P) loading over pre-settlement rates, failure of cold water fish populations to reproduce naturally, excessive growth of aquatic plants and invasions of non-native species (e.g., rainbow smelt, spiny water flea, zebra mussel, round goby).

There have been efforts to take action in the past through multi-partner initiatives such as the Lake Simcoe Environmental Management Strategy (LSEMS) which have made significant progress. For example, there have been significant reductions in phosphorus inputs to Lake Simcoe from inflowing rivers and in sewage treatment plant discharges.

Nonetheless, the Committee concluded that action is needed to address the causes of degradation of the lake ecosystem, specifically, to ensure that future development and land-use changes occur in a sustainable manner. In the Committee's opinion, the future health of Lake Simcoe and its watershed rests on this.

4. What is the potential for recovery and restoration of this ecosystem?

There is much scientific evidence that damaged lake ecosystems can recover if the stressors that affected them are removed or at least minimized. However, in order to ensure the long-term ecological health of the lake ecosystem, further reductions in the magnitude of the stressors that affect the lake and its watershed are essential. It is recognized that a return to the original pre-settlement conditions is not possible; nevertheless, a return to a healthy but different ecosystem is possible. Appropriate management targets and new initiatives are needed to meet these targets and to restore and sustain the lake's ecological health.

A healthy, self-sustaining ecosystem that provides social and economic benefits is the broad goal of lake ecosystem management. SciAC identified three fundamental principles that should be built into such a management regime:

1. To employ a precautionary approach to deal with the inherent variability and uncertainty of natural systems;
2. To recognize the limits of natural systems to deal with stressors imposed by human activities; and
3. To employ an iterative, adaptive approach that employs social and science-based planning, monitoring of system responses to learn and improve understanding, and uses new knowledge in a timely way to modify management regimes to adjust to change.

REPORT 2 SUMMARY: Stressors

The Lake Simcoe Science Advisory Committee was appointed in March 2008 to advise the Government of Ontario on how best to protect and improve the Lake Simcoe ecosystem. Specifically, the committee was asked by the government to use its expertise and its knowledge of current Lake Simcoe science to:

- evaluate the present state of the lake and its watershed;
- identify current and emerging pressures (stressors) on the lake and its watershed;
- advise on management approaches to mitigate the impact of these stressors; and
- propose a refined or enhanced monitoring framework to support the Lake Simcoe protection plan.

The Committee was asked to answer a series of questions on these topics. This report covers the Committee's findings related to its examination of the ecological health of Lake Simcoe and its watershed with respect to five of those questions.

5. What are the key current and future threats to the ecological health of the lake and its watershed?

The Science Advisory Committee identified eight categories of stressors that affect the ecological health of Lake Simcoe and its watershed: nutrients, primarily phosphorus; contaminants including pharmaceuticals and other organics, metals and sediments; pathogens, primarily bacteria; introduced species; climate change and other physical stressors; land use change; water extraction; and other human pressures such as fishing and boating.

Stressors are almost always a result of human activities. The Committee acknowledged that these stressors do not act independently; they will affect one another, and may also have interactive effects on the lake and watershed. For example, land use changes impinging upon the integrity of the terrestrial components of the watershed (e.g., wetlands, shorelines, riparian and upland forests), affect nutrient, organic and sediment inputs, and hydrology.

The Committee examined each of these stressors in depth, addressing the following topics:

- their causes and sources
- the ecosystem indicators that can be used to measure their effect
- the threshold levels that must be maintained to protect the ecological health of the lake and its watershed
- trends that are evident for each of the indicators
- future directions that can be anticipated
- areas or issues of particular concern ("hotspots").

6. To what extent does the health of Lake Simcoe depend on activities on the surrounding terrestrial landscape?

The Committee indicated that activities in the surrounding terrestrial landscape have a direct effect on the health of the lake. Most of Lake Simcoe's stressors are land-based, originating

from human activities in the watershed. Others such as air pollution bring pressure from beyond the watershed boundary. Key findings include:

- Stressor 1 – Nutrients: Urban, rural and agricultural uses on the landscape provide the majority of the phosphorus load to the lake.
- Stressor 2 – Pollutants: While a proportion of the pollutant load comes from long-range transport through the atmosphere, there are important sources in the watershed of e.g., pesticides (from use on agricultural fields, lawns and gardens), metals, sediment and organic material.
- Stressor 3 – Pathogens: Beach closures around Lake Simcoe result from high levels of bacteria.
- Stressor 4 – Invasive species: Practices on the surrounding landscape can have a significant effect on the transport and access of invasive species to the watershed.
- Stressor 5 – Climate change: The impacts of climate change will emanate from well beyond the watershed; however, they will affect physical and biotic attributes and ecological functions within the watershed.
- Stressor 6 – Land use changes: population growth, and changes in land use patterns and conversion of natural areas are key drivers of change in the Lake Simcoe watershed.
- Stressor 7 – Water extraction: The amount of water-taking, and its effects on the hydrology in the watershed is expected to increase and requires more study.
- Stressor 8 – Other human pressures: Increased fishing, boating and other recreational pressures are increasing with population growth.

7. To what extent does the health of Lake Simcoe depend on control of sources of pollution beyond its watershed boundary (e.g., atmospheric loading of P)?

The ecological integrity of Lake Simcoe is connected to activities that take place beyond its watershed boundary through the atmosphere, the hydrological cycle, and human activities. Some of its stressors – phosphorus loading, invasive species and climate change – originate well beyond the boundaries of the watershed. For example, 40 per cent of the phosphorus loading from the atmosphere to the lake is considered to come from sources beyond the watershed. In addition, a portion of the load of the contaminants such as mercury, lead and copper is a result of long-distance transport. By definition, invasive species originate from outside the Lake Simcoe watershed.

There is an urgent need to improve scientific understanding about the interactions of these stressors with the watershed in order to develop appropriate management targets and initiatives. By protecting aquatic resources and natural areas, achieving ecologically sustainable development and population increase, the impacts from stressors originating both inside and outside the watershed can be effectively reduced. These actions will contribute significantly to the continued social and economic benefits derived from Lake Simcoe and its watershed.

REPORT 3 SUMMARY: Management Approaches

The Lake Simcoe Science Advisory Committee was appointed in March 2008 to advise the Government of Ontario on how best to protect and improve the Lake Simcoe ecosystem. Specifically, the committee was asked by the government to use the current Lake Simcoe science to:

- consider the present state of the lake and its watershed;
- consider pressures on the system now and in the future;
- identify ecosystem features that need protection; and
- advise on appropriate management and a monitoring plan to support the protection strategy.

The Committee was asked to answer a series of questions on each topic. This report covers the Committee's findings related to its examination of the stressors affecting the ecological health of Lake Simcoe and its watershed with respect to four of those questions:

8. What are the major requirements for restoration of a naturally self-sustaining cold-water fish community in Lake Simcoe?

Numerous alterations to the Lake Simcoe ecosystem have negatively affected water quality and other changes such as the introduction of new species have changed the lake's ecological conditions and directly or indirectly affected the lake's native cold-water species (e.g., lake trout, lake whitefish, lake herring,). Because of their sensitivity to changes in water quality these cold-water species are excellent indicators of the ecological health of the lake. The lake trout is the most sensitive of these species because of its requirements for cold temperatures and well-oxygenated water throughout its life-cycle.

The Science Advisory Committee concluded that having dissolved oxygen levels in the deep waters during summer equal to or >7 mg/L is necessary for restoration of a naturally self-sustaining cold water fish community in Lake Simcoe. The Committee also concluded that reductions in total phosphorus loadings to the lake will be necessary to meet this goal of suitable oxygen levels. The recommended targets for phosphorus are >10 µg/L in the lake and <30 µg/L in the tributaries. There is some uncertainty associated with these targets and an adaptive management approach is required including monitoring of ecosystem responses as loading is further reduced.

In addition to the direct influence of phosphorus on water quality, other factors, including invasive species and degradation of near shore habitats, probably also contributed to the decline of the cold water community. Mitigating the impact of these and the other stressors acting on the lake, as outlined in Report 2, will be necessary to restore the native cold-water community and improve the over all health of the lake. Other factors such as major uncertainty associated with changing climatic conditions and the ongoing threat of new invading species necessitates active management interventions to restore healthy environmental conditions in which native species have the best possible prospects for survival.

Native species have a strong inherent capacity for recovery once suitable environmental conditions have been achieved. However recent improvements in natural recruitment of native species are unlikely to be sustained without ongoing efforts to further protect and improve environmental conditions for Lake Simcoe's cold-water fish and invertebrate populations.

9. What are the necessary spatial boundaries for the sustainable management of Lake Simcoe?

The Committee finds that, in addition to Lake Simcoe's drainage basin, groundwater aquifers and the airshed also need to be considered even though they may extend beyond the boundary of the watershed as defined by surface water flows. In particular, the Committee identifies the areas outside the watershed along the western portion of the lake as particularly critical. The western extent of the watershed is particularly narrow, is particularly subject to atmospheric transport because of prevailing winds and is an area of rapid and extensive development.

As a result, the Committee concludes that extended zones of protection are required and, further, that these should be based on atmospheric transport and ground water models, as well as on considerations for the appropriate protection of natural landscape features that contribute to the biodiversity, productivity and ecological integrity of the Lake Simcoe watershed.

Suggestions toward establishing an appropriate boundary are:

1. Map the airshed – particularly define sources of atmospheric dust and P additions to the lake that are relatively local but outside the watershed boundary.
2. Determine the extent of the groundwater aquifer and appropriate protections in conjunction with the Source Water Protection Act and Oak Ridges Moraine Protection Act initiatives that are already under way.
3. Map human population growth trajectories and the area of different land use planning protection measures in place (e.g. Greenbelt Act).
4. Map natural areas to the edges of the watershed and incorporate extensions or buffers that extend beyond the watershed boundary to provide protection as necessary to maintain biodiversity and the integrity of terrestrial features and land cover that provides contiguous habitats.

10. What approaches are required to mitigate the impact of the multiple stressors acting on Lake Simcoe?

To ensure the long-term ecological health of Lake Simcoe, and the associated health of its human communities, further reductions in the stressors that affect the lake and its watershed are essential.

This section contains the Committee's recommended management approaches for dealing with the complexity of issues affecting the health of Lake Simcoe, its watershed and people living in the watershed. These recommendations start from the premise that healthy ecosystems support self-sustaining, biologically diverse ecological communities and provide

maximal social and economic benefits to people by providing clean air and water, and renewable and useable resources that provide for healthy, viable human communities.

The Committee reviewed each of the eight major stressors, identified 18 management objectives and key targets to minimize impacts, improve and, where possible, restore the overall health of the Lake Simcoe ecosystem. This includes protecting its water and air quality, cold-water fish community, shorelines and aquatic habitats, groundwater systems, streams, river valleys and riparian zones, wetlands and forests in order to maintain the richness and diversity of native species. The sources of stressors have also been identified and recommended management approaches have been proposed.

The section concludes with a comprehensive listing of 42 recommendations that would assist in mitigating the eight primary stressors identified by the Committee. For nutrients and other pollutants, the recommendations address the sources of these stressors, whereas invasive species, loss of natural areas, and water extraction are considered specifically.

A summary of the 18 objectives can be found in Table 2 on page 61 and a consolidated list of all 42 recommendations can be found in Table 3 on page 79.

11. Is it necessary to identify areas of special concern for restoration and protection within the lake and its watershed (such as nearshore areas, bays, sub-watersheds, certain terrestrial features, riparian areas, wetlands, or headwater streams)?

Identification, protection and restoration of specific areas within the watershed that need focused management efforts are among the key steps needed to improve the long-term health of the lake.

This section describes three categories of areas of special concern that the Committee believes must be addressed within the Lake Simcoe watershed:

1. Areas that are degraded or impaired, with respect to downstream water quality in particular, include degraded or contaminated areas that affect the immediate or adjacent lands and waters, e.g. agricultural polders, Cook's Bay, Maskinonge River, and Kempenfelt Bay.
2. Areas that are of high ecological or socio-cultural value or sensitivity are associated with a special natural or cultural feature that needs protection from loss or alteration, e.g. northeast alvar habitats, groundwater infiltration zones, natural shoreline features, river valleys, wetlands and peat bogs. The Committee notes that additional work will be needed to locate and map some of these as part of developing the Protection Plan.
3. Areas of emerging concerns are threats or pressures that are occurring today or are likely to occur or escalate in the future and may include issues with great uncertainty about future consequences (e.g. the effects on aquatic organisms of pharmaceuticals discharged to water courses or the lake in treated sewage effluents, water extraction in cold water streams or associated aquifers, Trent Severn waterway with regard to invasion by exotic species.).

New management approaches are required to address and deal with these areas of concern, especially those which are complex and involve multiple activities and sectors.

REPORT 4 SUMMARY: Monitoring Approaches

The Lake Simcoe Science Advisory Committee was appointed in March 2008 to advise the Government of Ontario on how best to protect and improve the Lake Simcoe ecosystem. Specifically, the committee was asked by the government to use its expertise and current Lake Simcoe science to:

- consider the present state of the lake and its watershed;
- consider pressures on the system now and in the future;
- identify ecosystem features that need protection; and
- advise on appropriate management and a monitoring plan to support the protection strategy.

The Committee was asked to answer a series of questions on each topic. This report covers the Committee's findings related to objectives and targets, tracking the impacts of stressors affecting the ecological health of Lake Simcoe and its watershed and monitoring the response of the system to mitigative actions and best management practices designed to improve the ecological health of the Lake and its watershed:

12. What approach should be used to establish and maintain up-to-date objectives and targets for the lake and its watershed to support the proposed Lake Simcoe Protection Plan?

The Committee proposes that the first step to establishing and maintaining up-to-date objectives and is to develop a watershed-wide monitoring strategy that includes all partners and comprehensively addresses the eight identified stressors and indicators.

The work of groups such as LSEMS and the results of long-term monitoring programs, such as the lake water quality and the Lake Simcoe Fisheries Assessment Unit monitoring programs, constitute a major contribution towards the current understanding of the changing state of the lake. The expansion and enhancement of these programs is likely to be a major component of future programs. However, the Committee identified the need for additional monitoring of key ecological health indicators which is essential for establishing environmental goals, identifying emerging issues, filling information gaps, refining indicators of healthy conditions, setting new ecosystem objectives and making adjustments to improve management outcomes.

In brief, the Committee suggested the following approach to the development of a comprehensive watershed-wide monitoring strategy:

1. Address the magnitude of all eight identified stressors that impact the ecological health of Lake Simcoe in order to improve understanding of the mechanisms of action of all eight stressors.
2. Address the key indicators of ecosystem health that relate to the action of all eight stressors to ensure that management targets are being met, and thereby helping to select the most effective management and stewardship activities.

3. Address the key processes such as nutrient cycling, nutrient transport, carbon cycling, food web dynamics, and species interactions that maintain the ecological health of Lake Simcoe and its watershed and together define the state of the ecosystem.

The Committee suggested the adoption of an adaptive management approach, a structured process for continually improving management practices by testing selected options that are considered most likely to achieve specified management objectives, learning from their outcomes and making adjustments as required.

Monitoring is the cornerstone of a science-based adaptive management approach. It allows management options to be chosen based on the best available science with monitoring to track system responses, and uses new monitoring and research information to make adjustments to continually improve the effectiveness of management efforts.

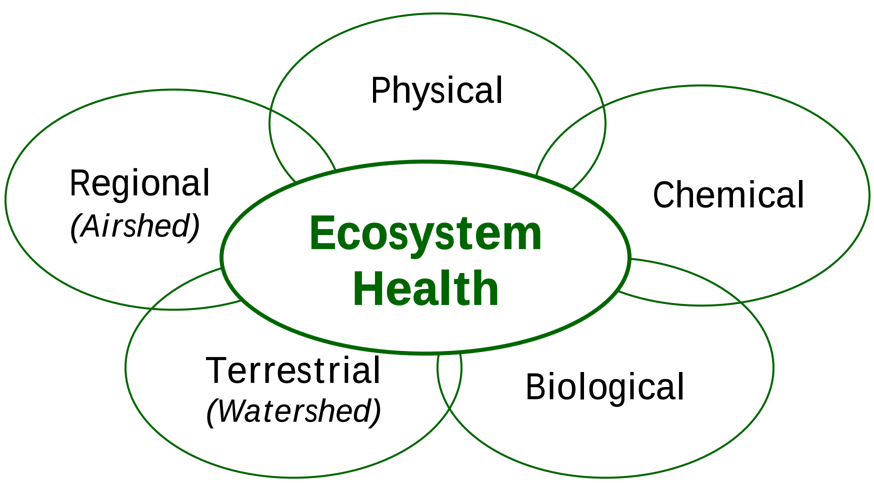
This section also outlines some of the key requirements to be considered during the development of any Lake Simcoe monitoring program. This includes the need for sustained funding, using monitoring to identify priority areas for implementation of management actions, improving existing monitoring programs in support of management and research initiatives to improve outcomes while gaining new understanding about system dynamics.

Q. 1 – What are the key attributes of the lake and its watershed that need to be considered when assessing the lake's ecological health?

A Definition of Ecological Health

Ecosystems consist of a multitude of components that serve different environmental functions and are linked together by a large number of processes. All of these processes involve the transfer of chemical constituents or energy between the different components. Examples of such processes common to all ecosystems include primary production (photosynthesis), nutrient transport, and respiration or decay of organic matter. A healthy ecosystem is one where the functions and processes represent a normal or reference state, that is, are comparable to conditions that occurred historically, or that occur currently in similar healthy ecosystems that have not been degraded by human activities. This implies not only that the same components exist but that the processes linking them were originally of the same magnitude; thus, a significant increase or decrease in, for example, species richness, the biomass of a specific component such as the algae, the flux of nutrients or the decay rate of organic matter indicates that the health of the ecosystem is changing. Further, ecosystem health can be characterized by the capacity to absorb external perturbations and rapidly return to an earlier state with resumption of normal functions (Callicott et al. 1999).

Figure 1 - Key Biotic and Abiotic Components and Processes that Affect a Lake Ecosystem



...ecosystems consist of a multitude of components that serve different environmental functions and are linked together by a large number of processes...

The key biotic and abiotic components and processes that affect a lake ecosystem include:

1. Physical components and related processes include morphometry (lake and river/stream shape), hydrology (water movement between atmosphere, watershed and lake), light regime, temperature regime, and water movements (currents, seiches and wind-induced mixing). The hydrology of the lake and watershed strongly influences both the supply of chemicals including nutrients and contaminants to the lake, and the flushing rate or water renewal rate of the lake which regulates the ability of the lake both to flush pollutants downstream and to bury them in the lake's sediments. Light (the radiant energy of the sun) is of fundamental importance to the entire dynamics of the lake because it provides the energy for the primary producers (algae and vascular plants) that provide the base of the food web in the lake and dictates the rates and extent of heating and cooling which in turn determines the types of species that can survive and flourish in the lake. The optical properties of the lake are also important regulatory parameters having profound effects on its mixing and circulation patterns (thermal structure) which in turn define habitat quantity and quality and influence the physiology and behaviour of all aquatic organisms living in the lake.

2. Chemical components and processes in the lake and watershed include the concentrations and cycling of essential plant nutrients that control the productivity of the plankton and benthic communities (e.g. submerged macrophytes). For example, excessive levels of the essential plant macronutrients (nitrogen (N) and phosphorus (P)) in surface waters often results in excessive rooted plant (macrophytes) and algal growth in the water body. The death and decay of macrophytes and algae can significantly change the concentrations of dissolved oxygen (DO) throughout the water column, which in itself is another critical component that characterizes and shapes a lake ecosystem. Other chemical influences on a lake ecosystem maybe expressed through impacts on water salinity (amount of dissolved minerals) and pH or the direct toxicity of the chemical to certain life forms.

Lake Simcoe Watershed Boundary

3. Biotic components and processes within the lake represent the distribution, growth dynamics and interaction of organisms including microbes, plants and animals. The growth and interactions (e.g. predation, competition, symbiosis, parasitism and commensalism) of aquatic organisms at all size scales can affect community structure. Likewise alteration of the physical-chemical habitat can affect the biological community. Different spatial zones of the lake (e.g. nearshore, offshore, shallow, deep water) are

inhabited by different biological communities with particular sensitivities to and requirements for the particular physical-chemical conditions at those locations.

4. Terrestrial (Watershed) components and processes include geology, physiography, hydrology, vegetation, soil, and land use. Physical changes to the terrestrial landscape such as erosion, habitat loss and fragmentation of wetland and forest communities, shoreline development and alteration, as well as water regulation can affect the ecological health of both the watershed and the lake.

5. Regional (Airshed) including climate are overarching components of individual watersheds that affect the physical, chemical and biotic components of the water body. These regional properties will also influence air-water and air-land interactions. Atmospheric inputs (e.g. wind blown dust) have been demonstrated to be an important component of nutrient and contaminant inputs to water bodies.

Q. 2 – What are the key indicators of these attributes that we can quantify and measure?

Ecological Indicators…

…are scientific variables (things that scientists measure) that help to simplify large amounts of complex information. Indicators are a guide used to determine if environmental quality or health is good or bad, e.g., dissolved oxygen and phosphorus concentrations are often used to characterize and communicate the condition or health of a lake to the public.

The following are some of the key indicators expressed as criteria that can be used to monitor the health of Lake Simcoe:

Physical

- sustainable water balance – low variability in lake water level and lake flushing rate;
- base flow in tributaries providing adequate habitat for their biotic communities;
- suspended sediment levels such that clean spawning beds for fish are available;
- water temperature within acceptable boundaries for cold-water fish populations; and
- no artificial obstructions to water flow (i.e. dams) that prevent migration of fish species that need access to tributaries rivers and creeks as spawning or nursery areas.

Chemical

- 7.0 mg/L or greater dissolved oxygen (DO) in bottom waters (end of summer minimum);
- 0.01 mg/L or 10 µg/L or less total phosphorus (TP) concentration in lake
- contaminant levels that do not restrict fish consumption by humans or fish-eating wildlife (e. g. loons, otters, mink);
- no significant undesirable trends over time in parameters of concern (e.g. increasing TP or decreasing DO); and

- appropriate water and sediment quality criteria are met, based on the Provincial Water Quality and Sediment Quality Objectives.

Biological

- no beach closures as a result of pathogens;
- a healthy, self-sustaining cold-water fish community;
- diverse composition of algae and macrophyte communities and biomass consistent with trophic status defined as “oligotrophic”;
- diverse native benthic invertebrate community composition and structure in littoral and profundal zones of the lake and in streams;
- diverse fish communities in the lake and streams consists of mainly native species;
- no new invasive non-native species;
- no noxious, harmful, or excessive blooms of phytoplankton or macroalgae; and
- healthy terrestrial biodiversity.

Terrestrial (Watershed)

- reduction in land conversion - intact and connected forests, wetlands and functional riparian habitats;
- habitat diversity;
- improved condition of shoreline vegetation (quality and extent of buffer);
- stable or improvements in status of species at risk or of conservation concern;
- no new introduced non-native species (plants and invertebrates); and
- no increases in commensal species (e.g. raccoons, rats, opossums).

Regional (Airshed)

- atmospheric deposition and precipitation quality similar to background levels measured at nearby reference stations; and
- minimal alteration to the hydrologic cycle through land use alterations.

Table 1 provides a summary of components and suggested indicators of environmental health for Lake Simcoe:

Table 1 - Components and Indicators of Environmental Health – Lake Simcoe

Components	*Lake Simcoe Indicator*
Physical	• Consistent water levels (volume, flushing rate) • Sustained base flows and temperatures in streams • Sediment levels, reduced suspended solids and deposits • Clean littoral zone spawning habitats • Diverse habitat structure • No artificial obstruction to water flow • Stable ground water and water table • Lake thermal regime
Chemical	• 7.0 mg/L dissolved oxygen in bottom waters • Less than 10 µg/L total phosphorus concentrations in lake water • No impact by contaminants – (reduced contaminant concentrations, e.g., mercury, organochlorine pesticides)
Biological	• A self sustaining cold-water fish community • Stable, healthy aquatic communities • No beach closures • Diverse composition of phytoplankton, algal and macrophyte communities and appropriate biomass • Healthy and intact trees and other native vegetation along the shoreline of the lake and its tributaries • Diverse zooplankton and benthic invertebrate community composition and structure characteristic of appropriate reference conditions • Diverse fish communities in the streams and the lake characteristic of appropriate reference conditions • Sustained populations and distribution of species at risk • No new introduced non-native species
Terrestrial (Watershed)	• Reduction in land conversion - % intact core and corridor habitat, including shoreline • Intact wetlands and riparian forests • Diverse communities of native wetland and terrestrial species • Compatible land use to sustain ecological integrity • Minimal impervious surfaces • Status of species at risk, conservation concern stable or improving, no increases in commensal species
Regional (Airshed)	• Atmospheric deposition and rain quality equivalent to background concentrations

Q. 3 - From an ecological perspective, how can the current state of Lake Simcoe and its watershed be described?

Lake Simcoe is the largest inland lake in southern Ontario, excluding the Laurentian Great Lakes (Winter et al.2007). Although it has been home to human settlers for thousands of years and has been subject to extensive land use changes, particularly in the last 200 years (Evans et al. 1996; LSEMS 2008), it remains an extremely valuable natural and recreational resource and an important source of drinking water. Over the past few decades in particular the lake's watershed has been subjected to extensive alterations by agricultural and urban development activities. Urban development has occurred over the past few decades as a consequence of population growth. The population of the watershed grew by 30% or 116,530 people from 1991 to 2001 (LSEMS 2003). Over 350,000 people now reside in the watershed (see Map 1) and growth continues at a steady pace, particularly in the southern and western portions of the watershed. Development, to accommodate both primary residents in urban areas and infrastructure related to recreation and tourism is proceeding in tandem with human population growth. Significant population growth in the watershed is forecasted to continue over the next two decades.

Impaired Ecological Health…

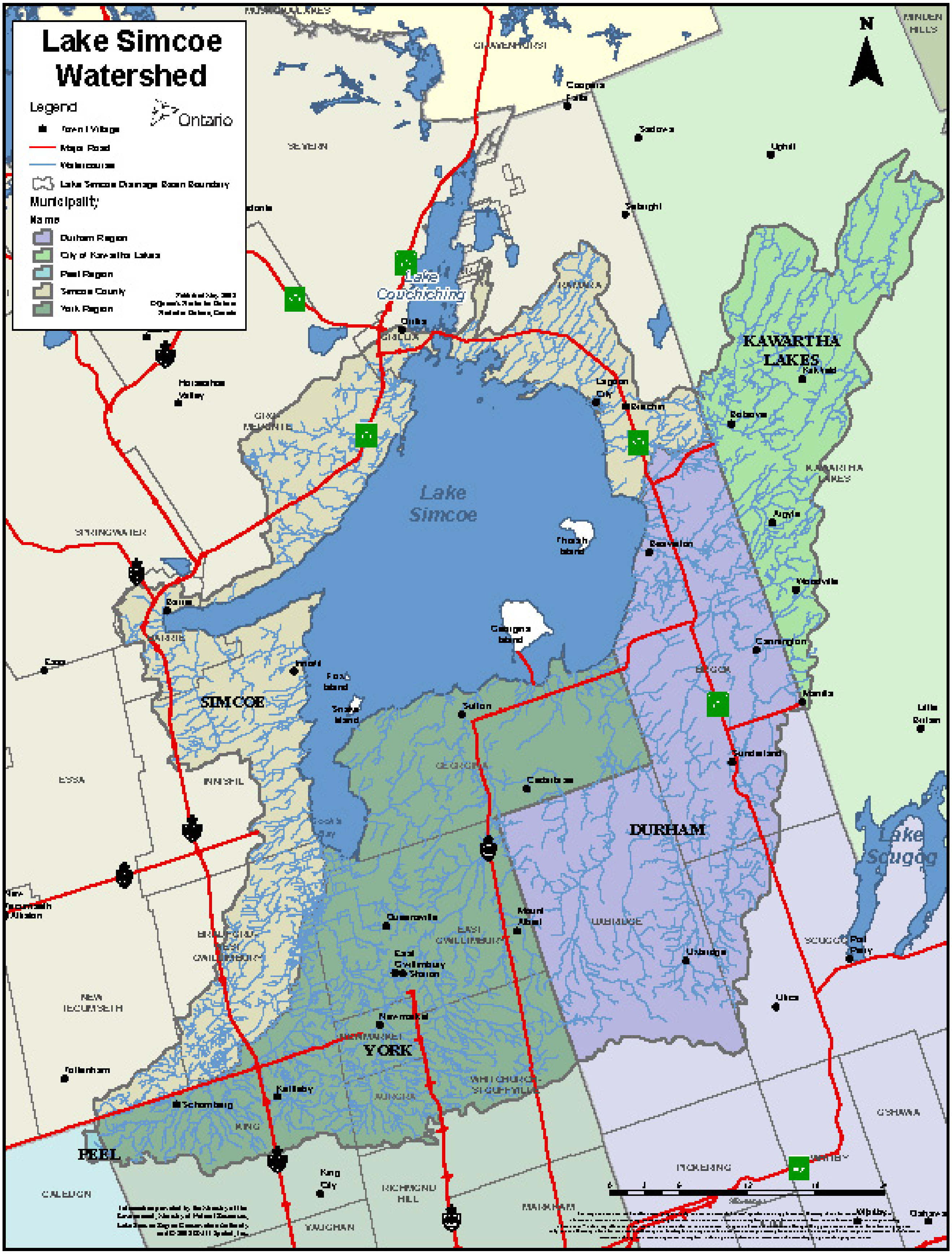
Phosphorus loading since European settlement of the watershed began has contributed to poor water quality, recruitment failure of cold-water fishes, alterations to food webs and excessive growth of aquatic plants.

Science, Research and LSEMS…

Nutrient loading abatement has led to significant reductions in P inputs to Lake Simcoe from inflowing rivers and STP discharges.

Water quality problems in Lake Simcoe have been documented since the 1970s and many of these problems have been attributed to an estimated three-fold increase in phosphorus (P) loading since pre-European settlement rates (Evans et al. 1996). Recruitment failure of the cold-water fish (lake trout, lake whitefish and lake herring), alterations to food webs and excessive growth of aquatic plants (both macrophytes and algae) have been attributed to this increase in nutrient inputs to the lake (Evans et al. 1996, LSEMS 2003). As the phosphorus concentrations and subsequently the plant biomass in the lake increased, the dissolved oxygen concentrations in the bottom waters declined in response to the increased respiration or decomposition of plant material, which negatively impacted the cold-water fish habitat. Although the greatest changes in the quality of the lake have resulted from land use changes, the appearance of invasive species, for example the recent invasion by the zebra mussel (*Dreissena polymorpha*), has also played a major role in shaping the ecology of the lake. Since the establishment of zebra mussels, internal phosphorus regeneration, as a result of their filtering, excretion and biodeposits, has increased in shoreline areas, making more nutrients available to the aquatic plants. Water clarity has also increased significantly allowing more light to penetrate the water. As a result, there has been an increase in macrophyte biomass in parts of the nearshore areas of the lake despite an overall reduction of phosphorus loading to the entire lake from a high of more than 100 t/yr to the most recent estimate of 67 ± 8 t/yr (mean ± standard deviation). However, current levels are still high relative to estimated baseline (or background) loading rate of 32 t/yr prior to large-scale human activities in the watershed.

Map 1 - Lake Simcoe Watershed



...recent zebra mussel invasion has played a major role in redefining the health of Lake Simcoe...

In recognition of the role of human activities in degrading the lake, various management initiatives (e.g., nutrient loading abatement, fish stocking and harvest regulations, and public education) have been implemented over several decades. Many of these management efforts, focusing on reducing P loading to the lake in particular, were initiated through a multi-partner program, the Lake Simcoe Environmental Management Strategy (LSEMS). These efforts led to a significant reduction in phosphorus inputs to Lake Simcoe from inflowing rivers and in sewage treatment plant discharge. There have been improvements in dissolved oxygen levels in the deep waters of the lake which now exceed the interim target of 5 mg/L, and there is evidence of some natural recruitment of lake trout. However, natural reproduction remains very low and lake trout and lake whitefish populations continue to be maintained or supplemented through hatchery stocking programs. Serious concerns remain regarding the potential effect of increased nutrient input to the lake as a result of the increasing human population (Winter et al. 2007, Evans et al. 1996). Action is urgently needed to ensure future population growth in the watershed occurs in a sustainable form.

In addition, the extent to which the current status of Lake Simcoe is and will be affected by other major environmental stressors notably climate change and new non-native species introductions, is poorly known. In combination with increased development and other changes in land use that are linked to a growing population, the future condition of Lake Simcoe is a cause for considerable concern and in need of immediate attention.

Q. 4 – What is the potential for recovery and restoration of this ecosystem?

Resilience and Resistance of the Lake Simcoe Watershed

There is much scientific evidence that damaged lake ecosystems can recover if the stressors that affected them are removed or at least minimized. Lake Simcoe and its watershed have been subjected to, and subsequently altered by, a number of stressors for many decades, and its ecological health has been seriously impaired as a result. Interim management practices have led to some improvements; for example, intervention through science, research and management initiatives have likely saved the native cold-water fish community. However, in order to

Lake Simcoe Can Recover...

...to ensure the long-term health of Lake Simcoe and restore its key ecological processes to reflect its natural condition (cold-water fish community and other native species) the magnitude of the 8 stressors need to be reduced for the entire watershed and management targets need to support these initiatives.

ensure the long-term ecological health of the lake ecosystem, further reductions in the magnitude of the stressors that affect the lake and its watershed are essential. It is recognized that a return to the original pre-settlement conditions is not possible; however, a healthy but modified ecosystem based largely on native species is possible and remains as the key management target.

...the ecological health of Lake Simcoe remains vulnerable...

Recently there are positive signs that Lake Simcoe has retained considerable resilience and is capable of returning to an earlier state as evidenced by initial recovery of several cold-water species. End-of-summer, deep-water dissolved oxygen concentrations have increased to >5 mg/L in recent years, from less than 2 mg/L during the 1980s and early 1990s, and since 2002 there has been some natural recruitment of lake trout, lake whitefish, lake herring, slimy and spoonhead sculpin, species that had limited or no natural reproduction for several years.

Nevertheless, the current ecological state remains vulnerable and at high risk. If P loading increases it will push the ecosystem towards a eutrophic (enriched) status which is not compatible with the overall goal of protecting the health of an oligotrophic (clear water) lake or the objective of restoring the cold-water fish community. Not only does the current P loading target have uncertainties inherent in it, but there may be unpredictable effects on nutrient and energy flow through the lake by the invading dreissenid mussels, as well as increasing impacts of other stressors such as climate change. Appropriate management targets (e.g., critical loads) supported by new initiatives are needed to meet these targets and to restore and sustain the lake's ecological health.

Moreover, some of the most significant changes to the ecosystem have occurred within the watershed. With parts of the watershed containing some of the fastest-growing urban centres in Canada, land use changes, including increasing development and urbanization and conversion of natural areas, have occurred at a rapid pace in the past decade. Although rates of deforestation were higher at the peak of agricultural activity in the last century and total forest cover has increased since that time, urbanization and the development of associated infrastructure (e.g. roads) by and large represent permanent land conversion. Further study is needed on sustainable development best practices and procedures.

A healthy lake is the goal of lake-ecosystem management. Management must be based on the following tenets:

- The lake is part of a larger ecosystem that includes its entire watershed but is also influenced by factors outside its watershed and should be managed in that context.
- Ecological health should be assessed with an understanding of the regional evolution and historic context that has shaped the system. We must be cautious about the phenomenon of "sliding baselines," or the loss of perception of change that occurs when each generation redefines what is "natural", particularly in a system like Lake Simcoe that has undergone change over the course of centuries.

Ecosystems...

...are complex, dynamic and characterized by change. Understanding the natural rates of change and direction is critical to understanding and protecting the ecosystem.

- Conservation strategies should maintain or restore key ecological processes that reflect the lake's natural or reference condition of co-evolved animal and plant communities.
- Because there are uncertainties in predicting the results of our management actions, and because ecosystems are constantly changing, management should be an iterative, adaptive process incorporating feedback through appropriate monitoring.
- Ecosystems have characteristic rates of natural change. Understanding rates and direction of change are critical to understanding the system, for example, the cycling of nutrients and energy. In some cases, the effects of a particular stressor or activity may not be known for some time. For example, we need to improve our understanding of the rate processes associated with climatic factors to anticipate and compensate for the effects of future climate change on the health of the Lake Simcoe ecosystem.

Ultimately, the goal of conserving the ecological health of Lake Simcoe and its watershed is best addressed by maintaining or restoring the diversity of genes, species and communities native to the region. This approach is consistent with the vision of ecological integrity, which implies wholeness or completeness of harmonious co-evolved communities of plants and animals (Great Lakes Commission www.glc.org/ecochart/principles and Parks Canada www.pc.gc.ca/progs/np-pn/eco_integ/index_E.asp).

Report 1 – References

Callicott, J.B., L.B. Crowder, K. Mumford. 1999. Current Normative Concepts in Conservation. Conservation Biology 13:22–35

Eimers, M.C., J.G. Winter, W.A. Scheider, S.A. Watmough & K.H. Nicholls (2005) Recent changes and patterns in the water chemistry of Lake Simcoe. Journal of Great Lakes Research 31:322-332.

Evans, D. O., K. H. Nicholls, Y. C. Allen, and M. J. McMurtry. 1996. Historical land use phosphorus loading and loss of fish habitat in Lake Simcoe, Canada. Can. J. Fish. Aquatic Sci. 53 (Suppl. 1): 194-218.

Lake Simcoe Fisheries Assessment Unit Update 2004-2 - A Changing Ecosystem: Exotic Species in Lake Simcoe

LSEMS (2003) State of the Lake Simcoe Watershed. Lake Simcoe Region Conservation Authority, Newmarket, ON.

LSEMS (2008) Lake Simcoe basin wide report. Lake Simcoe Region Conservation Authority, Newmarket, ON.

Winter, J.G., M.C. Eimers, P.J. Dillon, L.D. Scott, W.A. Scheider & C.C. Willox (2007) Phosphorus inputs to Lake Simcoe from 1990 to 2003: Declines in tributary loads and observations of lake water quality. Journal of Great Lakes Research 33: 381-396.

Q. 5 – What are the key current and future threats to the ecological health of the lake and its watershed?

The ecological health of Lake Simcoe and its watershed is affected by a number of stressors. Eight categories of stressors were identified:

1. **Nutrients** (primarily phosphorus, P);
2. **Pollutants** (including toxics, contaminants, pharmaceuticals and sediments);
3. **Pathogens** (primarily bacterial contaminants);
4. **Introduced species**;
5. **Climate change**;
6. **Land use change** (agricultural intensification, urbanization including industrial and residential development, recreation, aggregate and peat extraction);
7. **Water extraction** (inconsistent water supply); and
8. **Other human pressures in the lake** (e.g. fishing, fish stocking, boating).

These stressors do not act independently; they will affect one another, and may also have combined effects on the lake and watershed. For example, land use changes impinging upon the integrity of the terrestrial components of the watershed (e.g., wetlands, shorelines and forests), affect the hydrology of the system and nutrient and sediment inputs to the lake.

Each identified stressor is a result of a human activity (e.g., agriculture, urban development and human settlement, recreational activities). Stressors must be understood in terms of:

- Their causes and their sources;
- Selected indicators that can be used to measure their intensity and effects;
- The thresholds that are needed to maintain the ecological health of the lake and its watershed;
- The temporal and spatial trends that are evident for each of the indicators;
- The future trends and directions that might be anticipated; and
- Whether there are any areas of particular concern ("hotspots") around the lake or the watershed associated with any of the identified stressors?

Stressors….

…nutrients, pollutants, pathogens, introduced species, climate change, land use change, water extraction and human pressures have combined effects on Lake Simcoe and its watershed and do not act independently of one another…

…each stressor is a result of a human activity…

1. Nutrients

1.1 What are nutrients?

Nutrients (P and nitrogen, N) are naturally found in the lake and watershed, and are essential requirements for plant growth. Aquatic plants (both micro- and macroscopic) grow by absorbing N and P from the water or, in the case of rooted aquatic plants, from the sediments

(Kalff 2002). Phosphorus is the nutrient that usually limits the growth of aquatic plants and as a result an increase in loading of P to a lake can result in an increase in aquatic plant biomass. Plants actually consume inorganic carbon in the form of carbon dioxide (CO_2) and release oxygen (O_2) during the process of photosynthesis. Plants also respire, consuming O_2, and when plants die, they are decomposed by bacteria resulting in additional O_2 being consumed. Excessive aquatic plant growth in response to increased P concentration, is referred to as eutrophication, a process that can result in high rates of O_2 consumption sometimes resulting in severe depletion of oxygen and negative effects on aquatic organisms including invertebrates and fish. During summer periods when the lake is stratified and in winter when the lake is ice covered, the deeper parts of the water column are cut off from the atmosphere. At these times of year, oxygen can become severely depleted in lakes with high biomass of decomposing plant material. This dramatically affects the availability of suitable habitat for sensitive native fish species such as lake trout, lake whitefish, lake herring, slimy and spoonhead sculpins, as well as certain deep water benthic invertebrates and zooplankton species.


Sculpins

The management of nutrient inputs to Lake Simcoe has been primarily focused on P sources because it is the primary nutrient limiting plant and algal growth in the lake. Attempts to control N concentrations to control plant growth in Lake Simcoe would not be effective. However, at high concentrations some forms of N, notably ammonia and nitrate, become toxic to organisms.

1.2 Sources and Causes

Because of its link to dissolved oxygen (DO) and cold-water fish habitat, P has been the prime nutrient examined in Lake Simcoe and the subject of management action over the past three decades. The discussion in this section will therefore concentrate on P. Excessive P loading to the lake and its inflowing tributaries continues to be a key stressor in the Lake Simcoe watershed.

Eutrophication of Lake Simcoe…

…results in excessive growth of aquatic plants, and high rates of dissolved oxygen depletion which dramatically impacts the availability of suitable habitat for lake trout and other cold-water species.

Phosphorus inputs originate from:

i) Natural sources such as:

- Decay of organic material;
- Weathering of P-bearing minerals;
- Erosion of soils;
- Atmospheric deposition of airborne particulates; and
- Groundwater.

ii) Anthropogenic sources such as:

- Discharges from Sewage Treatment Plants (STPs) including human waste, and grey water containing kitchen waste and detergents.
- Erosion (by water or wind) and runoff from agricultural lands. Agricultural soils have typically received P containing amendments, such as fertilizers, manures and biosolids (i.e. solid wastes from STPs, paper mill wastes etc.) that have enriched the

surface soil in P relative to unfarmed soils. Waste management areas on animal livestock and dairy operations are also potential sources of P in runoff.
- Septic systems, particularly aging systems that have not been upgraded.
- Storm-water runoff from urban areas, which includes fertilizer applications to lawns, golf courses and parks, animal waste, and detergents from car washing, and runoff from roads and parking lots.
- Erosion (by wind and water) and runoff from construction sites. Bare and disturbed soils are prone to the erosive forces of wind and water.
- The atmosphere, as wet (rain and snow) and dry deposition. Anthropogenic sources of atmospheric P include long range sources such as the combustion products of fossil fuels and forest fires, and local aeolian (wind) transport from roads and areas having exposed soils (e.g., construction sites and bare agricultural fields).

In addition to the above-mentioned external inputs, there are also internal sources, principally the lake sediments. Decomposition of organic material in the sediments will result in the release of P. This P may enter the water to be used by other organisms (e.g. plants or algae) or can be attached to mineral components (such as iron oxides) present in the sediments. Phosphorus that has been stored in the sediments may be released into the lake under certain conditions (iron oxides that typically adsorb P will become soluble at low DO levels, resulting in the release of P into the water).

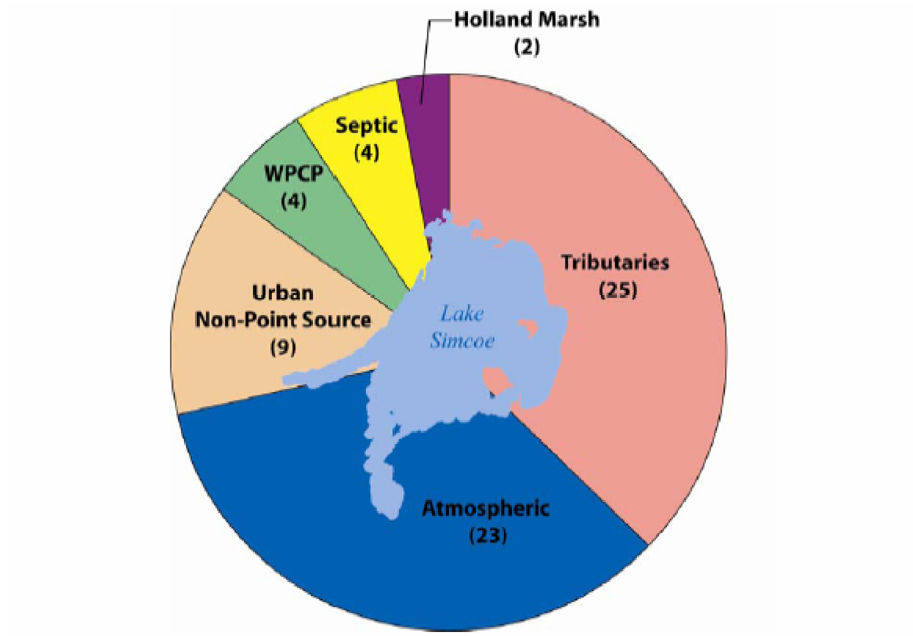


Figure 2 – Sources of P Loading (in average tonnes per year) in the Lake Simcoe watershed (total annual load of 67± 8 t/yr; average ± standard deviation loading from 1998-2004) (LSEMS 2008)

Phosphorus concentrations and P loading have been measured/estimated in Lake Simcoe since 1980. In estimating P loading to the lake, the following sources have been considered:

i) Water Pollution Control Plants (WPCP) – measured effluent from the STPs.

ii) Septic system release and runoff – estimated based on the number of shoreline properties within 100 metres of the lake that are not serviced by STPs.

iii) Water flowing from the Holland Marsh.

iv) Storm-water runoff from urban areas directly to the lake (urban non-point source).

v) Tributary streams flowing into the lake – partly measured, partly estimated to include the contribution of P from the runoff of rural, agricultural, and urban areas (those upstream of monitoring stations). Tributary inputs are further broken down into inputs from:
   a. Those where flow and water chemistry are gauged and monitored; includes approximately 50 % of the watershed area);
   b. Those where water chemistry is monitored and flow is modelled (ungauged and monitored; approximately 5 % of the watershed from 1998 to 2004); and
   c. Those where no measurements are made and loads are estimated (unmonitored; approximately 45 % of the watershed from 1998 to 2004).

vi) Atmospheric deposition – estimated for the lake based on both wet and dry deposition of P measured at designated stations.

As can be seen in Figure 2 on average the two largest sources of P loading from 1998 to 2004 were tributary inflows (25 t/yr) and atmospheric deposition (23 t/yr). However, due to the complex nature of the factors governing nutrient inputs to the system (e.g. hydrology, climate) there is substantial inter-annual variability in these sources; tributary inputs ranged from18 to 32 t/yr and atmospheric inputs varied from 16 to 38 t/yr. This variability needs to be considered, together with the modelling uncertainty inherent in estimating P loads to a lake.

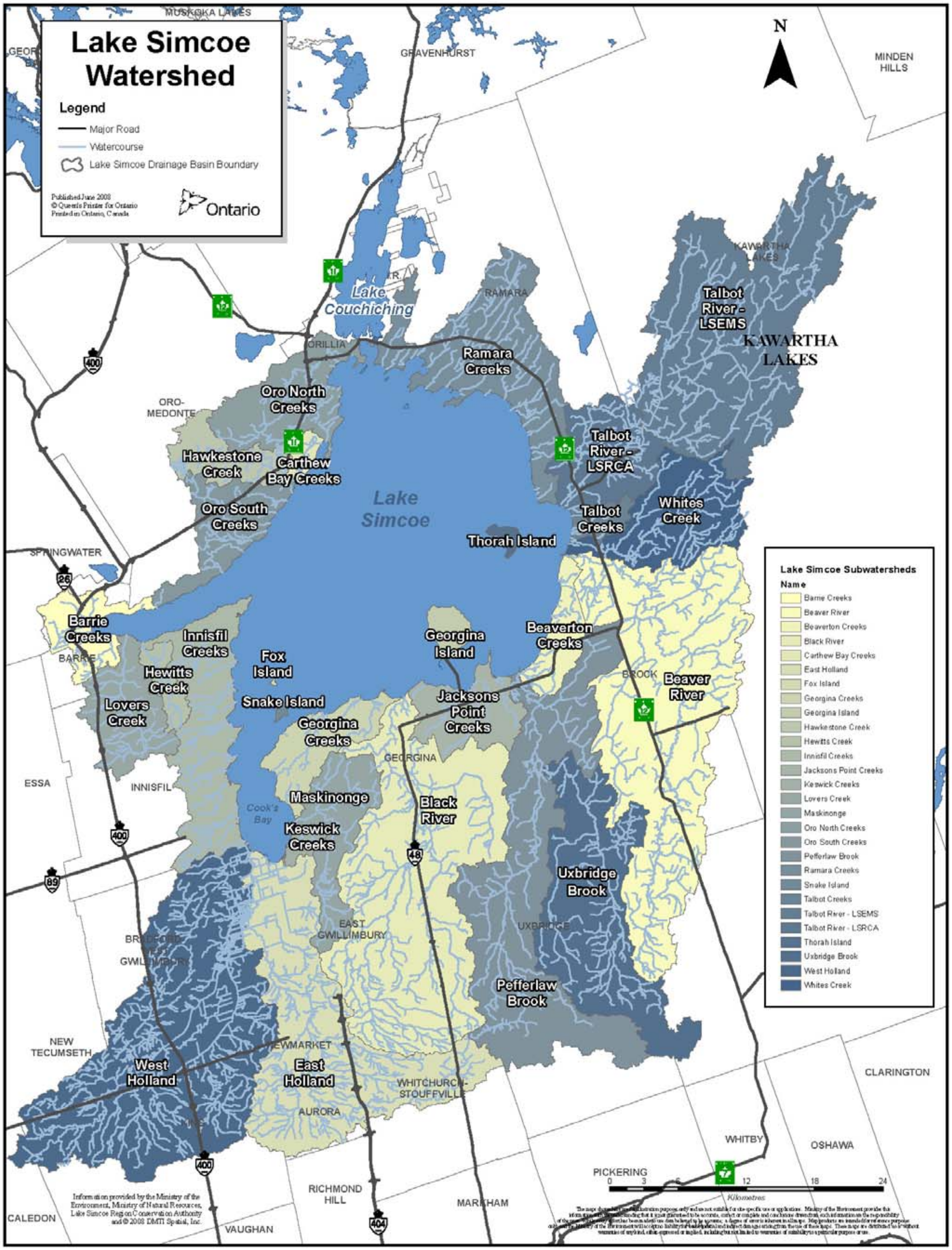
...determining the amount of phosphorus reduction to Lake Simcoe to improve lake trout habitat conditions is a complex process...

P Shunt

...P cycling in Lake Simcoe's near shore areas has been altered by the zebra mussel invasion. The mussels filter the water and enrich the near shore with P and other deposits that stimulates the growth of algae and rooted aquatic plants.

The relationships between P, plant biomass, reduced DO concentrations, and lake trout recruitment are well established (Evans et al. 1996, Nicholls, 1997, Lienesch et al. 2005). However, determining the amount of P reduction required to achieve desired dissolved oxygen levels is a complex process. Physical factors such as the depth and shape of the lake, the water residence time, and temperature will affect the relationships (Kalff 2002). The rate at which P is absorbed or released by lake sediments is also complex. Phosphate is tightly complexed to sediment and remains unavailable for plant growth when the surrounding water is oxygenated, but P is readily released from sediments when the water and sediments are deoxygenated (Kalff 2002). A further complexity in P cycling exists in lakes impacted by dreissenid mussels. Mussels remove particulate matter containing P from the water column through their filtering activity and, although a portion of the P is used in mussel growth, much of it is released back into the water in dissolved and in particulate form as feces and undigested ejected material. The feces and ejected material have the effect of enriching the sediments in P. This phenomenon has been termed the "nearshore phosphorus shunt" in the Great Lakes (Hecky et al. 2004) and

Map 2 - Lake Simcoe Sub-Watersheds



has been implicated in the dramatic increase in benthic filamentous algal biomass in nearshore areas in Lakes Erie, Ontario, Michigan and parts of Lake Huron (Higgins et al. 2005 and 2006, Malkin et al 2008). Thus in these Great Lakes, where phosphorus loading has been reduced in response to the implementation in 1972 Great Lakes Water Quality Agreement, nearshore areas impacted by dreissenid mussels are experiencing benthic algal biomass that is similar to that observed in these lakes during the pre-water quality agreement years (Higgins et al 2005, Malkin et al 2008).

Further increases in P in the nearshore zone could potentially cause a transformation from a diverse community of rooted aquatic plants to an undesirable situation dominated by one or a few species of attached filamentous algae.

1.3 Indicators

The levels of P loading are measured and predicted through the process described above as well as by the models developed during the Assimilative Capacity Study (Greenland 2006).

Other indirect measures of P change that can be used include:

- Lake water clarity, through Secchi disk monitoring;
- Phytoplankton biovolumes (total and of different classes of algae; in particular the formation of blooms of noxious blue green algae (Cyanobateria) is often an indication of high P concentrations);
- Dissolved oxygen concentration measured in the deep waters at the end of summer; and
- Increase in N compounds (ammonia, nitrate, nitrite) may also accompany P increases.

1.4 Thresholds

Phosphorus – a total P concentration of 0.02 mg/L (20 µg/L) in the lake and 0.03 mg/L (30 µg/L) in the tributaries are interim Provincial Water Quality Objectives (PWQOs). However, these are based on the risk of incurring potentially toxic cyanobacterial blooms. Evidence suggests that the protection of a self-sustaining lake trout population will require a level below 0.01 mg/L (10 µ/L) of TP in the spring when the water column is mixed (Nicholls, 1997).

PWQOs for Total Phosphorus...

TP threshold is 0.02 mg/L in the Lake and 0.03 mg/L in the streams to avoid algal blooms.

In Lake Simcoe, the level should be less than 0.01 mg/L in the spring to achieve conditions suitable for its lake trout population.

Dissolved oxygen – the preliminary target level for the lake as set by the Lake Simcoe Environmental Management Strategy (LSEMS) is a minimum end-of-summer deep water concentration of 5 mg/l. However, this is well below the level of (7 mg/L) considered necessary for the preservation of a healthy, naturally reproducing and self-sustaining lake trout population (Evans, 2007).

Dissolved Oxygen Criteria for Lake Trout...

...levels should be above 7 mg/L in the deep waters of the lake at the end of the summer to sustain Lake Simcoe's lake trout population.

Nitrogen (N) – two forms of N are of concern in surface and drinking waters:

- Nitrate-N - the Ontario Drinking Water Standard for nitrate-N is 10 mg/L and the new draft Canadian Water Quality Guideline (CWQC) is 2.9 mg/L of nitrate-N for surface waters. Amphibians are particularly sensitive to nitrate. Studies examining nitrate toxicity to selected native North American amphibian species indicate that nitrate concentrations required to kill 50% of the tadpoles are in the range of 13 to 40 parts per million (ppm). However, chronic effects including reduced feeding, reduced swimming, and developmental deformities occur at concentrations as low as 2-5 ppm in some species.
- Excessive algal and plant growth and changes in community composition can also occur at elevated nitrate-N concentrations. Although data collected by the University of Waterloo in 2007 indicates that plant growth in Lake Simcoe is P limited (i.e. will respond to reductions or increases in P loading) nitrogen processes need to be assessed in the Lake Simcoe watershed.
- Ammonia - the PWQO for ammonia (NH_3 un-ionized) is 0.02 mg/L. The percentage of un-ionized ammonia in aqueous ammonia solution for different temperatures and pH conditions are listed in a table in the PWQO document.

…LSEMS shows a decrease in P loading to Lake Simcoe…

1.5 Trends

The most recent published data from LSEMS shows a decrease in annual P loads to the lake. There were decreasing trends in loads from the tributary portion (1990 to 2004) and sewage treatment plants (1993 to 2004). The 6-year average total annual load from 1998-2004 was 67 ± 8 t/yr (mean ± standard deviation), a reduction from the more than 100 t/yr load estimated during the 1990s, and was below the LSEMS target level of 75 t/yr for most of the years. Phosphorus concentrations in the lake during the spring decreased over the period from 1980 to 2007 to an average of 11 µg/L since the late 1990s compared with an earlier average of 15 µg/L (J. Winter, personal communication). However, the average May to October phosphorus concentrations haven't changed significantly. Levels varied around 14 µg/L in the central basin and 15 µg/L in Kempenfelt Bay changing a lot from year to year (graphs of 1980 to 2003 trends are shown in Eimers et al 2005). The highest levels have been measured in Cook's Bay, averaging 17 µg/L. Overall, lake TP levels have not increased since the 1980s despite the increases in urban land cover and human population in the watershed.

P Loading may Increase with…

- *Intensified farming*
- *Sod farming and golf courses*
- *Lack of Storm-waterStorm-waterStorm-water Management*
- *Storm and runoff events*
- *Loss of natural areas*
- *Increased development*
- *Aging infrastructure*
- *Population growth*
- *Internal P loading*

The reduction of total P loading may not continue, and lake concentrations could increase given the following land use and related trends that have the potential to influence P (and other nutrient) loading to the lake in future:

- Increased population growth in the watershed will bring additional P loading pressure from STPs, septic systems, non-point source urban runoff, and service and support industries.

- Increases in sod farming and the number of golf courses in the watershed may increase P loading if P losses from these operations are greater than those from the land uses they replace.
- Shift in farm production from mixed farming to greater specialization in crop or livestock production.
- Lack of (or limitations with) strategies in place to maintain and clean storm-water management ponds. Existing urban storm-water control areas ponds fill up becoming less effective with age and could contribute P in the future.
- Changes in atmospheric deposition through wind transport – if climate change makes summers drier and warmer, it is possible that more P will be delivered to the lake through wind erosion and dust deposition.
- Increased clearing of land for development within and adjacent to the watershed would expose more soil during the construction phase, exposing more soil and associated P to loss through wind and soil erosion.
- All of these external parameters have natural variability and climate change has the potential to alter these dynamic loads through thermokinetic effects on production and decomposition processes. Increased variability can be considered a stressor and there is great uncertainty associated with changing climatic conditions.
- Aging recreational and cottage infrastructure is a source of P loading (e.g., faulty septic systems); it is a problem now and could get worse as systems age or seasonal residents become permanent residents.
- If management improvements related to new development (e.g., enhanced storm-water management, better control of wind erosion on development sites, prudent planning to site development to avoid shoreline areas and the loss of natural vegetation important in retaining nutrients) do not occur, an increase in development will lead to an increase in P loading.
- Internal loading (loading from sediments) needs to be assessed. Macrophyte growth, P retention and release, and zebra mussels could interact with climate change to influence internal loading rates and P cycling.
  - If the P loading were to increase leading to increased plant and algal biomass production, it could again drive the late summer DO to lower levels (mean less than 2 mg/L) which in turn would result in the release of more sediment- bound P into the water from the lake bottom sediments (Nicholls, 1995).
  - Currently, a positive feedback exists because the higher DO levels are reducing internal P loading from the lake sediments (i.e., P is effectively locked in the sediments).

1.6 Hot Spots

- Many of the rivers flowing into Lake Simcoe that are monitored currently exceed the PWQO for P. These include: the East and West Holland, North Schomberg, Upper Schomberg, Maskinonge and Black rivers as well as Tannery and Whites Creeks.
- Cooks Bay is a particularly "hot spot" for nutrients, and has experienced a nuisance level of macrophyte growth in recent years. Contributing factors are

the shallow depth of the Bay, high tributary loading of P, increased water clarity and nutrient cycling by zebra mussels. However, macrophytes play a positive role in the lake by limiting the growth of phytoplankton (they limit the amount of P available to phytoplankton) and by providing breeding, nursery, feeding and critical resting areas for many species of fish.

- Nitrate levels exceeding the 2.9 mg/L CWQG for the protection of aquatic life were recorded in the East Holland River and Uxbridge Brook, and on occasion in the Beaver River, from 2002 to 2005 (LSRCA 2005).

2. Other Pollutants

2.1 What are they?

Chemical Contaminants…

…are persistent in the environment and ay bio-accumulate in animal tissues which can pose a potential health risk to humans consuming these animals.

Suspended Sediments…

…can smother and reduce survival of lake trout and whitefish eggs, and can also clog gills of fish and invertebrates and disorient fish making them vulnerable to predators.

The "other pollutant" category includes the following:

- Suspended sediments;
- Chloride;
- Organic carbon;
- Iron;
- Toxic metals, notably mercury, chromium and aluminium;
- Organic chemicals PAHs, PHCs, PCBs, DDT, DDE, DDd, dieldrin, aldrin, chlordane, endosulfan, furans, and dioxins
- Inorganic pesticides (examples of inorganic pesticides include copper sulphate, ferrous sulphate and sulphur)
- Surfactants (derived from pesticides and household products like detergents);
- Pharmaceuticals and personal care products; and
- Atmospheric pollutants.

Sedimentation due to erosion and eutrophication has resulted in the build up of inorganic and organic material on lake trout spawning shoals. Generally these sites are relatively shallow and exposed to wave action, and so are cleaned during fall storms. Severe sedimentation of spawning shoals however, can smother and reduce survival of incubating lake trout and whitefish eggs. Infilling of rocky spawning substrates also makes deposited eggs more vulnerable to interstitial egg predators such as crayfish and mottled sculpins.

Sediment Loading in Lake Simcoe…

…Pre-settlement Sediment loading was approximately 27,000 tonnes annually compared to sediment loading of 64,000 tonnes per year during the 1980s.

In addition to the effects on eggs, suspended sediments can also clog gills of fish and invertebrates and disorient fish, making them vulnerable to predators and unable to find food. This is potentially an important factor for plankton feeding larvae of lake whitefish and lake herring which are particularly sensitive to this problem.

Chemical contaminants in the water can bind to the surface of sediment particles. The contaminants enter the food chain when the particles are filtered by aquatic organisms such as clams.

These contaminants can also accumulate in the bottom sediments where they may be "sequestered" until the sediments are disturbed by construction activities or anoxic conditions. Many of these chemical contaminants are persistent in the environment and can bio-accumulate in the tissues of fish and other species, and pose a potential health risk to humans or wildlife (loons, otters etc.) that consume fish. In addition some new contaminants such as pharmaceuticals that pass through sewage treatment plants may also persist at biologically active concentrations. The uncertainty of the long term effects of complex mixtures of such chemicals in waters, albeit at low concentration, is an emerging health concern for aquatic species and humans who use the water.

... atmospheric transport of contaminants can be regional or up to thousands of kilometres...

2.2 Sources or Causes

Industrial, urban and agricultural activities in the watershed are sources of contaminants. Other areas such as golf courses may also be a source of sediments during the construction phase and contaminants during the operational phase. Areas with permanent vegetative cover contribute much less sediment to water-bodies than disturbed soils because the vegetation and roots secure the soils, slow the water flow rate and trap fine material. Urban and agricultural development and row-crop agriculture on the other hand, increase sediment runoff to the lake.

As is the case for nutrients, an important source of contaminants today is atmospheric deposition – volatile contaminants (those that can evaporate) can be transported via local wind transport or from remote global sources and then deposited with local precipitation.

Specific sources of pollutants include:

- Regional and long range atmospheric transport; the source area can be thousands of km distant in the case of some pollutants such as mercury.
- Pesticides from agricultural areas, notably the Holland Marsh polders (drained marshlands).
- Pesticides from urban areas (lawn applications, golf courses and parks).
- Effluent from STPs can contribute metals, organic carbon and contaminants used in household applications, or from human waste. The presence of pharmaceuticals and other compounds that act as endocrine-system disruptors by mimicking or blocking

hormone activity, for example, are now recognized as a potential concern.

- Mercury from old sod farms and golf courses (from mercury-based fungicides) – this is not an issue in new practices because the use of these products has not been permitted since December 2000.
- Water and wind transport of sediment bound contaminants from active urban construction sites.
- Storm-water retention ponds may accumulate metals and pesticide residues in sediments which can be flushed into tributaries and the lake, particularly from ponds that are improperly maintained.
- Sewage sludge and other biosolids are potential sources of chemical contaminants.
- Sanding and salting of roads provide chlorides as well as sediments that are blown into the lake, or washed into tributaries in runoff.
- Marina development and increased boat use on Lake Simcoe are sources of hydrocarbons and contaminants in grey or black water discharges.

2.3 Indicators

Many but not all of the identified pollutants are measured in one or all of the following:

- Water samples;
- Sediment samples; and
- Fish tissue (consumption restrictions are published in the *Guide to Eating Ontario Sport Fish* www.ontario.ca/fishguide).

Bio-accumulative contaminants can also be monitored using biological samples (e.g. clams) or using passive samplers (e.g. semi-permeable membrane devices or tissue sponges). The toxicity of water or sediments can also be measured using standard toxicological procedures (e.g. the zooplankter, *Daphnia magna,* rainbow trout or fathead minnows bioassays).

2.4 Thresholds

There are published threshold levels for organic and inorganic pollutants found in the PWQOs. The *Guide to Eating Ontario Sport Fish* provides fish consumption restrictions based on contaminant levels in sport fish that are commonly caught and eaten.

...contaminant levels in Lake Simcoe fish have stabilized or decreased in the past 10-15 years...

2.5 Trends

Coring studies have shown that sedimentation in Lake Simcoe during the 1900s was approximately twice the natural, pre-European, mass sedimentation rate (Johnson and Nicholls 1989). Pre-settlement loads were estimated to be 27,300 t/yr compared to 63,900 t/yr in years prior to 1989.

No significant trends in total suspended solids have been found for Lake Simcoe tributaries (LSEMS 2008). However, two tributaries, Tannery Creek and the East Holland River, occasionally experienced elevated levels.

Chloride levels (likely from road salt) in Lake Simcoe have increased consistently over the past 20 years. The concentration measured at the lake's outflow in 2003 (~34 mg/L) was 3 times the level measured during the early 1970s (~11 mg/L; LSEMS 2005).

Based on the Provincial program that measures contaminant levels in sport fish, contaminant levels in Lake Simcoe fish appear to have decreased or remained stable over the last 10-15 years (S. Bhavsar, 2008). Fish consumption advisories have improved for walleye, whitefish and carp, while advisories for some species have increased (lake trout and largemouth and smallmouth bass). With reference to trends in toxicants and contaminants:

- DDT and its metabolites are still found in lake trout and lake whitefish tissue despite its discontinued use in the 1970s;
- Total PCBs in lake whitefish show a decreasing trend since the 1980s;
- Elevated organic and metal contaminants in many larger fish still require consumption restrictions; and
- Mercury levels in fish tissues have declined over the last 10 years.

2.6 Hot Spots

There are a number of specific pollutant hotspots in the watershed:

- Elevated chromium concentrations in water and sediments have been recorded in the main branch of the East Holland River and one of its tributaries, Tannery Creek (LSEMS 2008, LSRCA 2005). Elevated aluminium concentrations were also recorded in these rivers on occasion. Sediments in Kempenfelt Bay contained elevated levels of copper, zinc, lead, cadmium and chromium during the 1980s (Johnson and Nicholls 1988).
- Organochlorine pesticides were detected in a number of sediment samples collected downstream of the Holland Marsh during the Lake Simcoe Region Conservation Authorities Toxic Pollutant Screening Program (LSEMS 2008). In 2004 DDT, DDD, DDE were found at levels far exceeding the Canadian Sediment Quality Guidelines (CSeQG) for the Protection of Aquatic Life in the West Holland River and at two sites in Holland Marsh (LSRCA 2004).
- PAHs exceeded either the PWQO or the CWQG in water samples during low flows in six tributaries: East Holland River, Mount Albert Creek, Beaver River, Pefferlaw Brook, Uxbridge Brook and Black River. PAHs in sediments also exceeded the CSeQG in five tributaries - Barrie Creek, West Holland River, East Holland River, Tannery Creek in Aurora, and Black River in Sutton and at one site in the Holland Marsh (LSRCA 2004).


Polders

3. Pathogens

3.1 What are Pathogens?

Waterborne pathogens (including bacteria and viruses) pose a potential health threat to humans. The presence of bacteria in excess of the PWQO for body-contact recreation (e.g. swimming) is a direct threat to the health and the recreational experience of the people using the lake. In addition to the water-born fecal contaminants, pathogens of "new" diseases such as West Nile virus are also a concern in the watershed.

...high levels of bacteria in the water cause frequent beach closures around Lake Simcoe...

3.2 Sources or Causes

With the exception of insect-borne diseases, the primary source of pathogens is usually through fecal contamination from animals or humans. A water supply or a swimming area can become contaminated from any of the following sources:

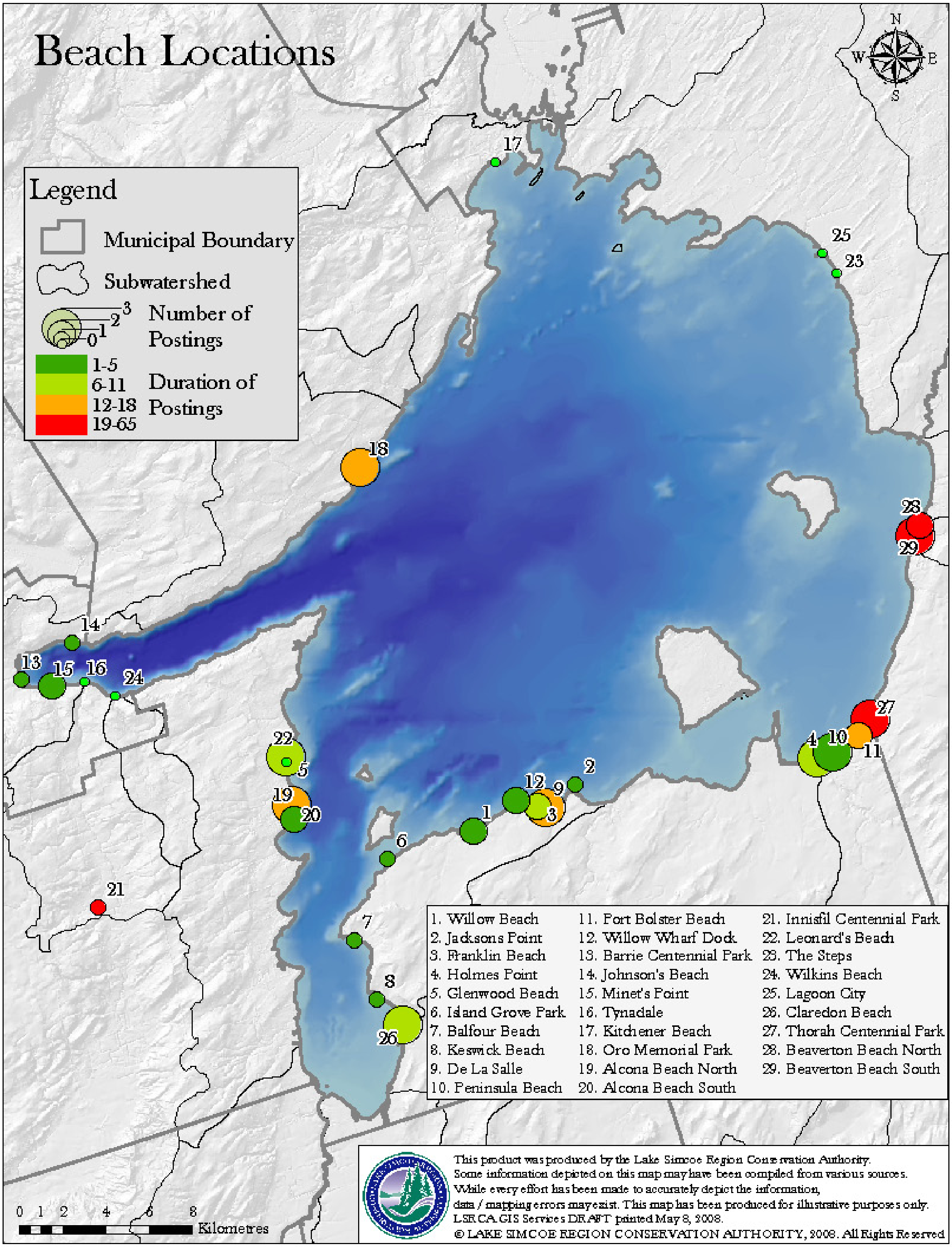
- Sewage Treatment Plant discharge/overflow;
- Boat traffic and discharge (black, brown, grey water);
- Sewage sludge and other biosolids;
- Livestock and dairy operations without proper manure management and storage;
- Storm sewer outflows;
- Waterfowl (examples include geese and cormorants); and
- Faulty septic systems.

The increasing frequency and duration of beach closures around Lake Simcoe is due to instances of bacterial contamination of nearshore waters. Beach closures are often associated with high precipitation and associated runoff events causing transport from septic systems and other sources. Longer and warmer open water seasons may aggravate this problem. In the Great Lakes Erie, Ontario and Michigan, decaying mats of the filamentous green algae *Cladophora* related to the dreissenid mussel colonization have been found to harbour concentrations of *Escherichia coli* that are greater than surrounding areas (Byappanahalli et al. 2007). While Lake Simcoe has not experienced such blooms of *Cladophora* in response to dreissenid mussel colonization, it has seen an increase in macrophyte biomass. Large decaying mats of macrophytes could provide the same anaerobic environment that permits *E.coli* growth.

3.3 Indicators

Beach closures, based on routine sampling of *E. coli,* are our best indicator of excessive levels of bacteria in the water. The number of closures each year, and the duration of each closure provide measures of the level of this stressor.

Map 3 - Beach Locations



3.4 Thresholds

- The presence of *E. coli* bacteria in excess of the PWQO of 100 counts per 100 mL of water (average of a minimum of 5 samples taken within a one month period) will cause the local Health Unit to close a beach for swimming

3.5 Trends

- The frequency and duration of public beach closures have increased since 2003.
- The durations of closures exceeded 35 days for 3 of the 27 beaches that were posted during 2006 and 10 beaches were closed for more than 10 days (LSEMS 2008). Only 3 beaches at the north end of the lake (Kitchener Beach, the Steps and Lagoon City) weren't closed during 2006.
- Several Georgina Island beaches have also been closed on occasion.

4. Invasive Species

4.1 What are Introduced or Invasive Species?

Invasive Species Can…

…cause major changes to ecosystems that they invade by disrupting food webs and in some cases excluding native species from their habitats and causing extinctions (e.g. native clams).

Zebra Mussels Have…

…physically restructured lake trout spawning habitats and have altered P cycling and energy flow in the nearshore areas of Lake Simcoe.

Pimentel et al (2000) estimated that invasive species cost the U.S $137 billion per year. We do not have a specific estimate of costs for Lake Simcoe. There are many aquatic and terrestrial species that are not indigenous to Lake Simcoe or the watershed. The introduction of invasive species can have devastating and often unpredictable impacts on the ecosystems that they invade, including loss of native species and disruption of nutrient and energy cycles.

Replacement of native species by introduced species may also affect the general stability of the ecosystem and major fluctuations in species abundances often occur following invasions. These changes often result in reduction in the productivity and abundance of native species. Lake trout, for example, appear to thrive best in simple communities with few competitors or predators, although this is mainly a problem in small lakes (Evans and Olver 1995). Lake trout can coexist with warm and cool-water species provided that adequate spatial habitat separation is available.

…native cold-water species are particularly at risk to the invasion by non-native species…

The aquatic invasive species known to be in the lake and their dates of introduction (where known) include:

- Common carp (*Cyprinus carpo*) – 1896
- Rainbow smelt (*Osmerus mordax*) – 1962
- Eurasian watermilfoil (*Myriophillum spicatum*) – 1984

- Curly-leaf pondweed (*Potamogeton crispus*)– 1961-1984
- Black crappie (*Pomoxis nigromaculatus*) – 1987
- Zebra mussel (*Dreissena polymorpha*) – early 1990s
- Spiny water flea (*Bythotrephes longimanus*) – 1993
- Bluegill (*Lepomis macrochirus*) – 2000
- Quagga mussel (*Dreissena bugensis*) – 2004
- Rusty crayfish (*Oronectes rusticus*) - 2004
- Round goby (*Neogobius melanostomus*) – 2006
- *(Echinogammarus ischnus)* – 2005

The presence of some of these aquatic invaders in the lake has caused significant and rapid changes to the Lake Simcoe ecosystem. For example, the rainbow smelt invasion was linked to decline in the lake whitefish population (Evans and Waring 1987) and the invasion of the lake by zebra mussels has been linked to system-wide changes including changes in water quality and increased production of aquatic plants. The expected relationships between phosphorus increase and oxygen depletion in Lake Simcoe has been complicated by the presence of zebra mussels (Evans et al. 2008). In studies in Lake Erie and Lake Ontario where the dreissenid mussels invaded a decade earlier than Lake Simcoe, the filtering of the mussels has resulted in increased water transparency and increased concentration of particulate and dissolved P in the nearshore areas (Higgins et al 2006, Malkin et al 2008). The increased water clarity and increased P in areas colonized by dreissenid mussels appears to have caused a dramatic increase in nuisance blooms of the filamentous green benthic alga *Cladophora* in these lakes. At the same time, the biomass of algae in the offshore of these lakes declined. However, it is not possible to infer if the offshore decline is linked to the increase in algal biomass in the nearshore or whether it is part of a response to some other larger scale ecological process affecting lakes both with and without dreissenid mussels.

...late summer dissolved oxygen levels are no longer directly lethal to young lake trout and continued improvements should result from controlling P loading...

In Lake Simcoe, dreissenid filtering has increased water clarity and increased P in the nearshore. Recent surveys (Depew et al 2008) have determined that macrophyte biomass has increased in the shallow areas of the lake. The increased oxygen concentrations in the deeper areas of Lake Simcoe suggest that like other lakes in the region, off shore waters have lower algal biomass post-dreissenid invasion. Chlorophyll observations in Lake Simcoe do not show this trend, however, but rather fluctuation around a steady mean since the mid 1980s similar to that seen for TP (Eimers et al 2005). It is unclear what the fate of the increased nearshore plant biomass will be in Lake Simcoe or its long term impact on trout habitat. This provides an example of the unexpected changes in lake dynamics that can occur with invasion of a non-native species. Late summer dissolved oxygen conditions are still low but no longer directly lethal to young lake trout and other cold-water species. This apparent improvement in one part of the system should not be mistaken for an overall improvement, nor for a reason to relax efforts to control phosphorus inputs. The issue of increased plant growth in the nearshore areas following zebra mussel invasion needs to be addressed in Lake Simcoe.

Rusty crayfish and round goby, a Ponto-Caspian european invader, both arrived in Lake Simcoe in 2004 and 2006, respectively. These species are currently poised to expand their populations with expected impacts on several native fish and invertebrate species, including lake trout through predation on developing eggs and larvae (alevins). Physical restructuring of the lake trout spawning habitat by zebra mussels by infilling of the interstices of preferred rocky habitats may reduce egg survival by facilitating increased predation on lake trout eggs as the abundance of rusty crayfish and round gobies increases. Another recent invader, *Dreissena bugensis*, the quagga mussel which first appeared in 2004, is expected to cause changes to the present distribution of zebra mussels, possibly with lake-wide ramifications for nutrient cycling and water quality.

Terrestrial invaders may also indirectly affect water quality through their impact on watershed vegetation. Examples in the Lake Simcoe watershed include exotic earthworms, purple loosestrife, ornamental jewel weed, dog-strangling vine, and some forest pests.

4.2 Sources or Causes

It is not always possible to pinpoint the sources of any particular introduced species, and there may be more than one potential source.

Some species have been introduced deliberately, but most have arrived through unintentional or accidental introductions.

The "unintentional" sources of species include:

- Movement through the Trent Severn Waterway – many species enter the Great Lakes through commercial ship ballasts, and a few find their way through the waterway to Lake Simcoe presumably by hitching a ride on boats moving through the system. For example zebra mussels probably arrived in this manner.
- Bait fish – some bait fish shipments or transport in live wells on boats from outside the watershed may include non-native species (e.g., black crappie, bluegill, rusty crayfish, round goby,), which are then released into the tributaries or the lake.
- Recreational boating and angling. Zebra mussels and spiny water flea are example of a species that may have entered the lake by traveling on boats, boat trailers or fishing gear that had picked up these species in other lakes.
- Fish stocking and aquaculture may bring pests or diseases such as VHS (viral hemorrhagic septicemia).
- The aquarium pathway may also pose a significant threat. Non-indigenous fish and plants enter the lake from ornamental ponds or aquaria if they are intentionally or accidentally released into the lake.
- Terrestrial invaders may come from horticultural stock (e.g. purple loosestrife), from bait (e.g. earthworms) or from other human transport (e.g. transported by moving infected firewood).

4.3 Indicators

The main indicator of introduced species is the observation of the presence of the organism in the lake or watershed. Records of the species' occurrence may then be associated with changes in the ecosystem. For example, zebra mussels were an obvious "new" species when first observed in 1991. In less than ten years they have significantly reduced the natural populations of mussels and clams through competition, and have had a system wide influence affecting many other species.

Another important indicator is a shift in ecosystem structure, usually evident soon after a new species arrives. There may be a dramatic increase in the abundance of a new invasive species which is often coupled with major decreases in native species. The abundance of the invasive species will sometimes decline over time as the new species comes into a form of equilibrium in their new environment. Fluctuations in the abundance of introduced species indicate that the ecosystem is in a state of transition, but these changes are not easy indicators to measure.

The interaction of species both existing indigenous species and introduced species often creates an unpredictable set of effects. For example, Round goby may partially reverse the influence of zebra mussels by direct predation, but the future extent and direction of interactions between the goby and other species in Lake Simcoe is uncertain.

Multi-species monitoring is the best approach for identifying invasive species and understanding their impacts on native species. However, as a general rule new preventative measures are needed to actively minimize the introduction of non-native species to Lake Simcoe and its watershed.

4.4 Thresholds

The only reasonable threshold for introduced species is zero. Although managers must contend with those that are present, the potential of introduced species for creating severe effects in the ecosystem demands a threshold of "zero tolerance for new invasive species."

4.5 Trends

Some of the species that have been in the lake for a while are stabilizing. For example:

- The common carp are not as abundant in Lake Simcoe as in other lakes, and their population is fairly stable;
- The density of zebra mussels in littoral areas appears to have reached a maximum however colonization of deeper waters by zebra mussels or by the more recently invading quagga mussels is anticipated;
- A high density of rusty crayfish was observed at an island in Lake Simcoe (Grape Island) in 2007 and has displaced the formerly abundant northern crayfish at that location; and

- The recent introduction of the round goby to Lake Simcoe is expected to have some effect on the abundance of zebra mussels through predation. Its impact on other members of the fish community is uncertain, although egg predation on native species including lake trout, lake whitefish and lake herring is a concern.

Round Goby

The future is uncertain with respect to the next introduction. Some items of concern include:

- Disease and pests in terrestrial species, e.g., sudden oak death, emerald ash borer;
- Disease in fish, e.g., VHS which was first discovered in some fish species found in the Great Lakes;
- Any new species that have already invaded the Great Lakes, since the Trent Severn Waterway is a potential transmission route. A long list of Great Lakes aquatic non-indigenous species is available from the National Center for Research on Aquatic Invasive Species website at: http://www.glerl.noaa.gov. Any of these species that have not already invaded Lake Simcoe are potential invaders, including *Hemimysis anomala* (the bloody-red mysis) and *Cercopagis pengoi* (the fish-hook waterflea); and
- Climate change may provide temperature conditions that favour new species in the watershed.

4.6 Hot Spots

Local areas and activities of concern that are potential sources of invasive species, include the Trent Canal system and bait, aquarium and live fish dealers, especially those located on inflowing rivers. These are probable sources of previous introductions and require special monitoring and management attention. Observed locations within the lake of rusty crayfish and round goby are critical monitoring hotspots for assessment of range expansions and species impacts to improve understanding of the ecology and the influence of these species.

5. Climate Change

5.1 What is Climate Change?

Fossil fuel use and land use changes generate greenhouse gases such as carbon dioxide, methane and nitrous oxide which are now known to contribute to a warming climate. Predictions from climate change models indicate that significant changes from the historic patterns of climate and weather in Ontario will occur in the future. Changes include more extreme weather events, resulting in both droughts and flooding, and more frequent occasions of high wind velocities. Overall, mean annual air and surface water temperatures are expected to increase for both lakes and streams.

Ecological Impacts on Lake Simcoe from Climate Change…

- *Extreme weather events causing drought and flooding*
- *Increasing temperatures*
- *Fire risk*
- *Increases in sediment and P loading*
- *Increased aquatic plant growth*
- *Reduction of cold-water habitat*
- *Changes to spring freshet (snowmelt)*
- *Longer growing season*
- *Milder winters*
- *Less ice cover*
- *Shifts in species composition*

The expectation is that the impacts of climate change will worsen in the foreseeable future. In the section on "Indicators", a number of trends are identified, but the future effects of climate change are very uncertain and the way the lake will respond is not understood.

....climate change impacts will worsen in the coming years...

The following are potential impacts on the Lake Simcoe watershed from an expected warmer climate:

- Water balance changes – changes in precipitation and increased evaporation;
- Duration of lake stratification – a reduced ice cover, increased lake temperatures, earlier onset of stratification, and delayed turnover;
- Possible changes in the depth and persistence of the thermocline;
- Increases in sediment and nutrient loading as a result of increased flooding;
- Seasonal variability in biotic response and mismatches in the timing of life stage events and associated species interactions, such as between larval fish feeding requirements and zooplankton pulses;
- Increased growth of aquatic plants including algae;
- Reduction of thermal habitat for some species and increases for others; and
- Shifts in community structure at various trophic levels.

Lehman (2002) explored the impacts of climate warming on the Laurentian Great Lakes using various climate models and the models predicted a longer stratified season, deeper seasonal thermocline depth and a stronger stability of the thermocline. These changes in physical properties of the lakes would be expected to result in lower algal biomass due to stronger nutrient limitation in the stratified periods and light limitation due to the deeper mixing depths. Deeper and longer stratification would reduce the volume of the hypolimnion, however this could be offset be decreased algal inputs into the hypolimnion. Stainsby et al (2008) examined thermal profiles from Kempenfelt Bay over the period 1980 to 2007 and reported that the duration of the stratified period has increased significantly over that period.

Climate change can indirectly exacerbate the other stressors/threats, e.g. increases in pathogens and disease; increase in wind and flood transportation of nutrients, sediments and contaminants; periodic failures of sewage and flood control infrastructure; loss or damage to susceptible aquatic and terrestrial habitats; shifts or loss of biodiversity within woodlands, riparian zones and wetlands; and loss of seasonal access to fish and wildlife species (e.g. reduction in duration of the ice fishing season).

5.2 Sources or Causes

The following elements of climate change are expected to have the greatest impact on ecological processes in Lake Simcoe:

- Generally increased mean annual and seasonal air and water temperatures;
- Greater extremes in air temperatures;
- Reduction of ice cover;
- Changes in evapotranspiration;

- Reduced water infiltration during storm events and more intense runoff;
- Reduction in ground water and artesian flows; and
- Increased number and intensity of weather events (more flooding, higher winds).

5.3 Indicators

Indicators of climate change impacts on Lake Simcoe might include:

- Earlier ice out, which may cause lower end of summer DO;
- Higher water and littoral zone sediment temperatures. There is a strong negative relationship between hypolimnetic temperature and DO concentrations in Lake Simcoe indicating a direct thermokinetic effect on microbial respiration as would be expected (Evans et al. 2008);
- Longer ice-free and stratification period developing earlier in the year and lasting longer during the summer into fall;
- Longer ice free season could affect algal growth and shift species composition.
- Increased temperatures in the littoral zone may encourage macrophyte growth and zebra mussel production, leading to inshore enrichment and possibly increased E. coli in inshore waters;
- A longer period of stratification in the lake may affect fall spawning of fish thereby shortening incubation times and possibly leading to poorer survival and reduced recruitment;
- Reduced runoff of water to the lake could slow the flushing of the lake. However, the runoff under climate warming may be associated with more intense weather events, which may increase sediment and organic carbon loading;
- Changes in the spring freshet (snow melt). If snow quantity is less it is unlikely that the freshet would be more intense, however, this effect is uncertain;
- A longer growing season will allow new tree and plant species to colonize the watershed. Those that are rapidly reproducing and adapted to warmer conditions will be most successful;
- Milder winters will favour pathogens that are generally more common further south. These include: Lyme disease (deer ticks), West Nile virus (mosquito), and epidemic typhus (tick);
- Milder winters will also allow terrestrial species (e.g. opossum) commonly found in more southern climates, to establish themselves in the Lake Simcoe region. Some of these will out-compete existing species (e.g. Carolina chickadee replacing black-capped chickadee);
- Decreasing depth and persistence of snow cover may be deleterious for some species and their ranges will contract further northward; and
- Species as diverse as fish, amphibians, birds, butterflies and mammals may change seasonal phenomena such as reproductive and migration patterns, which could directly affect survival within the lake or watershed.

5.4 Trends

Some additional trends might include:

- Greater seasonal variability in climate, also an important management concern.

- Increased frequency of intense weather, e.g. 1 in 100 year flood, events.
- Changes in the seasonal pattern of rainfall. More rainfall in the fall and spring would cause increased runoff, whereas lower levels of rain in summer would result in more drought conditions (and erosion of exposed soils by wind).
- Fire risk is not known but may be elevated during summer. There are large forested areas, and older plantations that could be susceptible to desiccation and fire in the future.
- Possible increase in insect pests as drought conditions weaken tress and mild winters allow improved overwinter survival of insects.

Overall, we need to improve our understanding of local biotic responses to climate trends.

5.5 Hot Spots

The entire Lake Simcoe basin is a hot spot in regard to possible effects of atmospheric pollution and climate change. However there are probably parts of the watershed that are more or less vulnerable based on hydrology, size and disturbance levels. Comparative sub-watershed studies would provide the opportunity for understanding impacts from various types of stressors including climate change. The sub-watersheds vary widely in their current environmental health creating the opportunity for a comparative approach (perhaps report card format) to be quite effective.

6. Land Use Change

6.1 What is it?

The ecosystem health of the watershed relies on the maintenance of healthy terrestrial components. Natural areas, wetlands, woodlands, and shorelines of the lake and its tributaries, have suffered important loss and fragmentation as the watershed has become increasingly developed, particularly in the western portion of the watershed where population growth and accompanying development activities have intensified. Overall, 47 % of Lake Simcoe's approximately 2800 km^2 terrestrial watershed is now agricultural, while urban and rural development and roads make up 14 % (Scott et al, 2005). Although the majority of the lake's shoreline lake has been developed, there are some areas, mostly in the northeast sector of the lake, that remain in a relatively natural condition. Shoreline hardening by the clearing of the natural vegetation along the shore, construction of concrete docks and walls adjacent to the water's edge, and cutting the vegetation to the water's edge disrupts ecologically and hydrologically important land-water linkages. For example, simply changing the water depth gradient might exclude certain species and life stages from inhabiting the littoral zone. Large continuous forests, characteristic of much of the watershed a century ago, have been fragmented by roads, agriculture and urbanization, eroding both the extent and quality these habitats. Most relatively unfragmented forest blocks that remain tend to be concentrated in the eastern part of the watershed. Wetlands, however, have suffered significant alteration throughout the watershed since European settlement began, as is common throughout southern Ontario.

...Lake Simcoe's watershed has been fragmented by development which has caused the loss of important natural areas, wetlands, woodlands and shorelands...

6.2 Sources or Causes

Loss of terrestrial natural areas can be attributed to the following changes or pressures on the watershed:

- Expanding urbanization and development pressures associated with heavily populated centres and along major roadways of the watershed;
- Shoreline development and hardening of shorelines by marinas or private owners;
- The conversion of seasonal cottages to full-time residences brings more people to the lake on a full-time basis, and often involves building larger homes, and more shoreline infrastructure (docks, breakwalls, boathouses) with accompanying loss of littoral zone fish habitat and fragmentation of riparian and forested lands;
- Expanding recreational development, including development of golf courses and marinas with increased contaminant loads and loss of habitat and biodiversity;
- Peat extraction operations in wetland areas, with loss of aquatic and terrestrial biodiversity;
- Expansion of aggregate extraction activity in the watershed, particularly on the Carden Plain;
- Dams and other control structures in tributaries negatively impact fish habitat and obstruct migration routes; and
- Removal of forest cover in riparian or upland areas alters hydrology, flux of materials, nutrients and organic carbon and reduces habitat for amphibians and terrestrial species with loss of productive capacity and biodiversity.

Loss of Terrestrial Natural Areas in the Lake Simcoe Watershed is caused by...

- *Development pressures and expanding urbanization*
- *Shoreline development and redevelopment*
- *Aggregate and peat extraction*
- *Removal of riparian and upland forests and wetlands*

6.3 Indicators

Key indicators are:

- The change in proportion of land in wetland, forested valley land, riparian and upland forests;
- The degree of fragmentation of these types of natural areas;
- The amount of shoreline that is either undeveloped or maintained in a naturalized state;
- Changes in the status of rare, threatened and endangered species;
- Changes in overall species abundances and biodiversity; and
- Physical parameters such as flow regimes, water table, ground water, water temperatures, extent of vernal pools, and the extent of coldwater streams.

These indicators provide a gross measure of the stressor, and a more refined measure would include assessment of the health of the natural areas – e.g., the size, age and species composition of forests and wetlands.

Any loss in the abundance of species or biodiversity in the affected terrestrial or the aquatic ecosystems would be an indicator of stress.

6.4 Thresholds

Land uses are mapped and recorded in a GIS format, providing a means to chart changes in land use and in natural areas. Specific thresholds and targets are difficult to set regarding the erosion of biodiversity, but studies have been conducted on the size of forest blocks necessary to maintain good quality nesting habitats for southern Ontario songbirds, herpetiles, and other wildlife. Similarly, habitat quality for species relying on wetlands can be measured through the amount and level of fragmentation of such areas. In reference to the health of the lake, use of the Assimilative Capacity Study Model can predict the effects of these land use changes on nutrient loading to the lake.

6.5 Trends

- Population growth is continuing in the watershed with concomitant demands for new infrastructure and development;
- Development along the Lake Simcoe shoreline is continuing;
- Agricultural production will change in response to relative prices of various crops and livestock, climate conditions, and regulatory requirements. Current trends are to reduced numbers of livestock, particularly cattle, and relatively stable crop acres; and
- There is significant pressure for expanded aggregate extraction in the Lake Simcoe watershed given the ready access and quality of the aggregate that exists within the watershed (LSEMS, 2003).


Highway 400

6.6 Hot Spots

- Areas in the watershed identified for urban growth (e.g. Barrie, Newmarket etc);
- Peat extraction is a locally important activity in the wetland areas in the southeast of the watershed; and
- The demand for aggregate in southern Ontario has meant a concentrated and intense demand for use of the limestone in the Carden Plain, to the east of the lake. Extraction can have an impact on the local hydrology, potentially affecting baseflow to tributaries as well as affecting the diversity of the local flora and fauna.

7. Water Extraction

7.1 What is water extraction?

Uses that extract large amounts of groundwater and surface water (individually or cumulatively) may cause reduced baseflow to streams, lowering of the water table, and reduced overall inflow of water to the lake. Climate change may exacerbate these impacts because of an altered pattern of seasonal rainfall, greater evapotranspiration, and potentially greater amounts of water extraction for urban and agricultural use.

Current water balance data indicates that maintaining base flow in high risk tributaries (e.g., the Maskinonge River and Whites Creeks; LSEMS 2008) is a major problem. This problem can be expected to be further aggravated and to extend to other sub-watersheds as water demand increases with the combined effects of a growing human population, further hardening of surfaces with urban expansion and climate change.

7.2 Sources or Causes

Uses for which water is extracted include:

- Agricultural and horticultural irrigation;
- Municipal water supply;
- Golf course irrigation;
- Commercial bottled water; and
- Other industrial uses.

...climate change will impact the global water cycle and we can anticipate a supply and demand conflict for fresh water resources...

7.3 Indicators

- Baseflow stations measure the actual flow of tributaries in the watershed, and the LSRCA and the Provincial Groundwater Monitoring Network monitor groundwater depths;
- Lake water levels are monitored by Parks Canada; and
- Annual water budgets provide measures of water stress.

7.4 Thresholds

- Water taking is controlled through Permits to Take Water issued by MOE. Permits issued to take water are for quantities in excess of 50,000 L/day from surface and groundwater sources (irrigation, bottled water); no permit is required to extract water at lower volumes;
- Sustained baseflow in inflowing tributaries to ensure aquatic habitat protection aquatic biodiversity and production and achievement of sub-threshold levels of contaminants; and
- Maximum annual lake level variation equivalent to natural pre-settlement variation.

7.5 Trends

- Baseflow station data of main tributaries show no clear trends since 1990, only annual variability;
- Trends in groundwater levels are not yet available;
- Complaints from the community over illegal water takings have increased significantly in recent years (LSEMS 2008);
- Newmarket and Aurora STPs were diverted decades ago; two pipelines were constructed that bring water in from Lake Ontario and send sewage back down to be treated. However, Keswick, Sutton, Innisfil, Holland Landing, and Brantford are supported by water taken directly from Lake Simcoe;
- Water extraction for water bottling does not appear to be an issue at present, but future demand may increase; and
- Taking into account the variability resulting from climate change, we can anticipate a supply and demand conflict with demand exceeding supply – the supply may change seasonally, but not annually and this will have implications for all users; demand will increase with population growth but supply will remain the same or possibly decline with warming climate.

8. Other Human Pressures

8.1 What are other Human Pressures?

There are other human uses that can potentially exert stress on the lake and its watershed. These include recreational uses and associated activities such as: fishing, hunting, snowmobiling and boating, as well as resource management actions such as imposing fish size and harvest regulations and fish stocking.

8.2 Sources or Causes

Increasing human populations in the watershed and in the Greater Golden Horseshoe area generally continue to put recreational pressure on the lake. Winter fishing pressure is increasing and Lake Simcoe is the most intensively fished inland lake in Ontario

Use of live bait increases the risk of release of non-native species. Increased emerald shiner harvest from Lake Simcoe itself for bait, may represent a threat to nearshore fish communities.

Boating poses a risk to water quality by introducing petroleum hydrocarbons to the aquatic environment. Boating also increases the risk of invasion of non-native species and is also associated with habitat losses related to development of moorage facilities.

Stocking the lake with fish predators can also have negative ecological implications for the ecosystem. This is of particular importance in Lake Simcoe since the lake trout's traditional primary diet item, the native lake herring, declined unexpectedly. A similar population crash occurred for the introduced rainbow smelt which had temporarily replaced lake herring in the lake trout diet. Concern has been raised about the possible role of high stocking rates on mortality rates of these two prey species. Stocking of hatchery fish also has the potential to

affect the survival of wild adult and juvenile lake trout thereby possibly suppressing recovery of the native lake trout stock (Evans and Willox 1991).

8.3 Indicators

Indicators of fishing stress and the health of fish populations are measured during routine monitoring and creel surveys conducted by staff of the MNR Lake Simcoe Fisheries Assessment Unit (www.mnr.gov.on.ca/en/Business/LetsFish).

8.4 Thresholds

Multiple stressors on the Lake Simcoe ecosystem, especially water quality changes, habitat loss, invading species, and climate change, have the capacity to severely affect the production and biodiversity of fish and other aquatic species . This necessitates ongoing monitoring of key indicators, for example indicators of fish population health such as spawning stock size, growth rates, and recruitment (i.e. number of young fish produced) success. Changes in other stressors may require adjustment of harvest rates for various fish species to reduce fishing mortality. A deterioration of ecosystem health will be expressed in lower fish production capacity, reduced resistance to stressors and will require harvests to be lowered.

8.5 Trends

- Population growth in the watershed is continuing, and this will likely mean increased pressures for recreational uses (fishing and boating);
- Should the length of time that the lake remains frozen decrease, ice-fishing during the winter will be reduced and open water seasons will increase resulting in new harvest regimes and possibly requiring new adaptive regulatory approaches; and
- Cottage conversions and more intensive use of shoreline properties will likely occur as cottage infrastructure ages and more of the baby boomer generation reaches retirement age.

Other Human Pressures Impacting Lake Simcoe and its Watershed include…

- *Increasing human population and associated activities*
- *Pond-based bait farming*
- *Boating*
- *Fish stocking*
- *Cottage conversions*
- *Recreational development*

Q. 6 - To what extent does the health of Lake Simcoe depend on activities on the surrounding terrestrial landscape?

What takes place on the surrounding terrestrial landscape has a direct effect on the health of the lake because the lake is a natural catch basin for all activities on the land. Accumulation of persistent pollutants in the lake sediments is a good example of this. Population growth, agriculture, shoreline development, and loss of natural habitat are all occurring as a result of human activity within the

Population Growth, Agriculture, Shoreline Development and Loss of Natural Habitat is…

… influencing the health of the Lake Simcoe. Land use patterns and conversion of natural areas have been the drivers of change in the watershed. What takes place on the surrounding land has a direct impact on the health of Lake Simcoe because the lake is the natural "catch" basin for all human activity.

terrestrial landscape of the watershed and are influencing the health of the lake.

Many of the lake's stressors are land-based and originate from human activities within the watershed. However, some of the stressors such as air pollution and invasive species bring pressure on the lake from far beyond the watershed boundary.

...clean water is the product of a healthy watershed...

Stressor 1 – Nutrients

With the exception of a portion of the atmospheric sources and internal P loading, all the sources of P loading to Lake Simcoe can be attributed to what is happening on the surrounding landscape.

- The total amount of P in the soil would naturally range between 300 – 1000 ppm depending primarily upon the parent material. Additions of P fertilizer, manures or biosolids to agricultural lands can significantly increase (by 25-100%) the soil P level if applied at rates greater than crop removal (Ellert and Gregorich 1996).
- Farm management practices and site characteristics (slope, soil type etc.) can affect the forms, amounts and pathways of P loss from agricultural lands.
- The transport of P through the atmosphere represents a high proportion of the total P loading to the lake, and the majority of the transport is from local sources. Approximately 60% of the annual atmospheric P load is estimated to be derived through wind erosion from local construction sites, agricultural fields and quarry operations. Land management activities occurring on the local terrestrial landscape therefore affect the input of P to the lake by atmospheric deposition.
- Another large proportion of the P loss from watershed to the lake is in surface runoff as sediment-bound and dissolved forms. In addition, although traditionally regarded as a surface runoff problem, there is increasing evidence of P transfer in subsurface flow.

Atmospheric Deposition of P Loading to Lake Simcoe…

…60% of the atmospheric P load is derived through wind erosion from construction sites, agricultural fields, and quarry operations.

Stressor 2 – Other Pollutants

While a certain amount of the contaminant source can be attributed to long-range transport through the atmosphere, there are inputs to the lake from activities in the watershed. For example, pesticides, mercury and chromium derived from historical agricultural and industrial practices within the watershed have probably accumulated in lake and river sediments, in particular in Cook's Bay and Kempenfelt Bay, resulting from past and present intensive human activity. Pesticides originate from use on lawns, gardens and agricultural fields along the tributaries, the lake shoreline, and in the watershed and from use for mosquito control.

Stressor 3 – Pathogens

Beach closures resulting from high levels of bacteria can be attributed to the runoff from surrounding local areas, originating from urban and agricultural areas. On some beaches, waterfowl (e.g. geese and cormorants) excrement is a probable source of pathogens.

Stressor 4 – Invasive Species

Invasive species by definition have been introduced and originate beyond the watershed boundary. However, recreational activities (e.g. fishing and live bait use) and management practices (hatchery stocking) have a significant potential effect on the transport and access of invasive species or new genetic stocks to the watershed. This is an area of concern and actions are needed to minimize the risk of new introductions.

Stressor 5 – Climate Change

The impacts of climate change will emanate from beyond the watershed, although it is important to consider the contribution of the Lake Simcoe watershed itself to the regional production of greenhouse gases. A current study (P. Dillon, personal communication) has the objective of quantifying Lake Simcoe's contribution, and it appears from early results that the carbon footprint in the watershed is negligible when compared to the global contribution. Nevertheless management actions are required to minimize and adapt to the influences of climate change on physical and biotic attributes and ecological functions within the watershed. The issue of water extraction is an example where adaptation will likely be required.

… management actions will have to minimize and adapt to the influences of climate change in order to conserve Lake Simcoe's resources (attributes and ecological functions)…

Stressor 6 – Land Use Changes

Fundamental changes to land use patterns and conversion of natural areas since European settlement of the watershed began during the 1800s have been some of the ultimate drivers of changes experienced in the lake (Evans et al 1996). These changes express themselves through the other stressors described in this report, such as increased nutrients, contaminants, pathogens, invasive species, and water extraction pressures.

Stressor 7 – Water Extraction

The amount of water-taking, and its effects on the hydrology in the watershed requires more study.

Water Permit applications are required and issued by the MOE, with minimum thresholds based on site-specific conditions, with consideration for the catchment as a whole. Permits are required for any water-taking greater than 50,000 L/day. However, multiple un-regulated takings of 50,000 L/day could have a major impact. There are also many cases of illegal water-takings that could be causing considerable impacts on the hydrology of the watershed.

Using the analogy of a leaky faucet in household, this unmonitored loss is a concern that requires urgent attention.

The impact of water-taking by the water bottling industry is not considered to be an issue at present, but could become a problem if the activity increases in the watershed.

Stressor 8 – Other Human Pressures on the lake

Intensive fishing and increased boating pressures emanate from the increase in human residents residing in or visiting the watershed, with Lake Simcoe itself as a prime destination.

Q. 7 - To what extent does the health of Lake Simcoe depend on control of sources of pollution beyond its watershed boundary (e.g., atmospheric loading of P)?

The ecological health of Lake Simcoe is connected to its watershed and others beyond its boundaries through the atmosphere, the hydrological cycle, and human activities. Urbanization, invasive species and climate change, as well as all those stressors associated with these pressures, all have a profound effect on the health of Lake Simcoe.

For example, local and long-distance transport of atmospheric pollution - in the form of P or contaminants tied to particulate matter, and invasive species - have been impacting the lake since the 1970s:

- 40% of the P loading from the atmosphere is considered to be from sources beyond the watershed;
- Much of the total input of contaminants such as mercury, lead and copper is a result of long-distance transport; and
- Invasive species that originate from outside the watershed are likely introduced by anglers, bait dealers, and through boat traffic through the Trent Severn Waterway.

Improve Scientific Understanding…

…in order to develop appropriate targets and initiatives for the 8 stressors there is an urgent need to improve our scientific understanding about the complex interactions among stressors and with the environment within Lake Simcoe.

Lake Simcoe and its watershed are vulnerable to many stressors. Phosphorus loading in particular is of fundamental importance, as is water and landscape management within the watershed and prevention of new species introductions. The unpredictable problems created by the zebra mussel, and the implications of the other existing and future stressors, means that there is no margin for error in the current P loading target. There is an urgent need to improve scientific understanding about the interactions of these stressors within the watershed in order to develop appropriate management targets (e.g., critical loads) and initiatives. Continued and enhanced P load reduction will improve the margin of error, especially with the certain pressures of population growth and urbanization. Managing the watershed's contribution of P loading, contaminants and resource exploitation, while minimizing the loss of natural areas to achieve ecologically sustainable development, will help to mitigate the impacts from sources outside and inside the watershed. Directing

population growth to existing settlement areas, encouraging intensification and reducing pressures on natural areas will all help achieve increased protection for the lake. Finally, socio-economic forces occurring well beyond the watershed will dictate the scale, intensity, and pace of human development patterns that will in turn drive the extent to which pollution will need to be controlled.

Report 2 – References

Bhavsar, S.P., E. Awad, J.G. Winter and R. Fletcher (2008) Temporal Trends of Legacy Contaminants in Lake Simcoe Fish. Presentation at the 51st Annual Conference on Great Lakes Research"

Byappanahalli, M.N., L.W. Richard, D.A. Shivelya, et al. (2007) Population structure of Cladophora-borne Escherichia coli in nearshore water of Lake Michigan. Water Research 41: 3649-3654

Depew, D.C., T. Ozersky, A. Houben, S.J. Guildford, R. E. Hecky, R.E.H. Smith and D. R. Barton (2008) Macrophytes in Cooks Bay: effects on water quality and nutrient cycling. Presentation at the 51st Annual Conference on Great Lakes Research.

Eimers, M.C., J.G. Winter, W.A. Scheider, S.A. Watmough & K.H. Nicholls (2005) Recent changes and patterns in the water chemistry of Lake Simcoe. Journal of Great Lakes Research 31:322-332.

Ellert, B.H. and E.G. Gregorich (1996). Storage of carbon, nitrogen and phosphorus in cultivated and adjacent forested soils of Ontario. Soil Science 161:587-603.

Evans, D.O. (2007) Effects of hypoxia on scope-for-activity and power capacity of lake trout (Salvelinus namaycush). Canadian Journal of Fisheries and Aquatic Sciences 64:345-361.

Evans, D.O. and C.H. Olver (1995) Introduction of lake trout, Salvelinus namaycush, to inland lakes of Ontario, Canada: factors contributing to successful colonization. Journal of Great Lakes Research (Supplement 1): 30-53.

Evans, D.O., K. H. Nicholls, Y. C. Allen, and M. J. McMurtry (1996) Historical land use phosphorus loading and loss of fish habitat in Lake Simcoe, Canada. Can. J. Fish. Aquatic Sci. 53 (Suppl. 1): 194-218.

Evans, D.O. and P. Waring (1987) Changes in the multispecies winter angling fishery of Lake Simcoe, Ontario, 1961-1983: invasion by rainbow smelt and the roles of intra- and interspecific interactions. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 182-197.

Evans, D.O. and C. C. Willox (1991) Loss of exploited indigenous populations of lake trout, Salvelinus namaycush, by stocking of hatchery-reared, non-native stocks. Can. J. Fish. Aquat. Sci. 48 (Suppl. 1): 134-147.

Evans, D.O., A.J. Skinner, G. Yunker, J.G. Winter, and J.K.L. La Rose (2008) Hypolimnetic temperature and dissolved oxygen in Lake Simcoe before and after invasion by zebra mussels and implications for lake trout. Presentation at the 51st Annual Conference on Great Lakes Research.

Greenland (2006) Assimilative Capacity Studies CANWET™ modeling project Lake Simcoe and Nottawasaga River basins. Final Report. Greenland International Consulting Ltd, Collingwood, ON.

Hecky, R.E., R.E.H. Smith, D.R. Barton, S.J. Guildford, W.D. Taylor, M.N. Charlton and T. Howell (2008) The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 61: 1285–1293

Higgins, S.N., R.E. Hecky and S.J. Guildford (2006) Environmental controls of Cladophora growth dynamics in eastern Lake Erie: application of the Cladophora Growth Model (CGM). Journal of Great Lakes Research 32: 629–644.

Higgins, S.N., E.T. Howell, R.E. Hecky, S.J. Guildford, R.E. Smith (2005) The wall of green: the status of Cladophora glomerata on the northern shores of Lake Erie's eastern basin, 1995-2002. Journal of Great Lakes Research 31: 547-563.

Johnson, M.G. and K. H. Nicholls (1988) Temporal and spatial trends in metal loads to sediments of Lake Simcoe, Ontario. Water, Air and Soil Pollution 39:337-354.

Johnson M.G. and K. H. Nicholls (1989) Temporal and spatial variability in sediment and phosphorus loads to Lake Simcoe, Ontario. Journal of Great Lakes Research 15: 265-282.

Kalff, J. (2002) Limnology: Inland water ecosystems. Prentice-Hall.

Lake Simcoe Fisheries Assessment Unit Update (2004) A Changing Ecosystem: Exotic Species in Lake Simcoe. 2004-2.

Lehman, J.T. (2002) Mixing patterns and plankton biomass of the St. Lawrence Great Lakes under climate change scenarios. Journal of Great Lakes Research 28: 583-596.

Lienesch, P.W., M.E. McDonald, A.E. Hershey, W.J. O'Brien and N.D. Bettez (2005) Effects of a whole-lake, experimental fertilization on lake trout in an oligotrophic arctic lake. Hydrobiologia 548: 51-66.

LSEMS (2003) State of the Lake Simcoe Watershed. Lake Simcoe Region Conservation Authority, Newmarket, ON.

LSEMS (2005) Lake Simcoe Water Quality Update 2000-2003. Lake Simcoe Environmental Management Strategy Implementation Technical Report No. Imp. B.20. Lake Simcoe Region Conservation Authority, Newmarket, ON.

LSEMS (2008) Lake Simcoe basin wide report. Lake Simcoe Region Conservation Authority, Newmarket, ON.

LSRCA (2004) Lake Simcoe watershed toxic pollutant screening Program. Lake Simcoe Region Conservation Authority, Newmarket, ON.

LSRCA (2005) Lake Simcoe watershed 2005 environmental monitoring. Lake Simcoe Region Conservation Authority, Newmarket, ON.

Malkin, S.Y., S.J. Guildford and R.E. Hecky (2008) Modeling the growth response of Cladophora in a Laurentian Great Lake to the exotic invader Dreissena and to lake warming. Limnology and Oceanography 53:1111–1124.

Nicholls, K.H. (1995) Some recent water quality trends in Lake Simcoe, Ontario: Implications for basin planning and limnological research. Canadian Water Resources Journal 20:213-226.

Nicholls, K.H. (1997) A limnological basis for a Lake Simcoe phosphorus loading objective. Lake and Reservoir Management 13:189-198.

Pimentel, D., L. Lach, R. Zuniga and D. Morrison (2000) Environmental and Economic Costs of Nonindigenous Species in the United States. BioScience 50:53-65.

Scott, L.D., J.G. Winter & R.E. Girard (2006) Annual water balances, total phosphorus budgets, and total nitrogen and chloride loads for Lake Simcoe (1998-2004). Lake Simcoe Environmental Management Strategy Implementation Phase III Technical Report No. Imp. A6. Lake Simcoe Region Conservation Authority, Newmarket, ON.

Sharpley, A., B. Foy and P. Withers (2000) Practical and innovative measures for the control of agricultural phosphorus losses to water: An overview. Journal of Environmental Quality 29: 1-9.

Stainsby, E.A., J.G. Winter and A.M. Paterson (2008) Trends in the thermal dynamics of Lake Simcoe from 1971 to 2007. Presentation at the 51st Annual Conference on Great Lakes Research.

Winter, J.G., M.C. Eimers, P.J. Dillon, L.D. Scott, W.A. Scheider & C.C. Willox (2007) Phosphorus inputs to Lake Simcoe from 1990 to 2003: Declines in tributary loads and observations of lake water quality. Journal of Great Lakes Research 33: 381-396.

Q. 8 – What are the major requirements for restoration of a naturally self-sustaining cold-water fish community in Lake Simcoe?

Lake Simcoe is a natural lake trout lake (OMNR 2006) and is currently managed with emphasis on restoration of its natural lake trout population. A prerequisite to the survival of a lake trout population is sufficient dissolved oxygen (DO) in the deep waters (hypolimnion) during summer. The mean end-of-summer (i.e. worst case) hypolimnetic DO concentration for Lake Simcoe has been estimated to have been approximately 8 mg/L prior to European settlement and under these circumstances Lake Simcoe would have supported a strong, naturally-reproducing lake trout population (Evans et al., 1996). Late-summer hypolimnetic DO concentrations (at 4.5 mg/L) were much below these pre-disturbance levels when measured in 1975, and continued to decline to less than 3 mg/L during the late 1980s and early 1990s (Evans et al., 1996), thereby falling below the critical threshold (3 mg/L) for survival of lake trout. However, current measurements show an increase to above 5 mg/L in most years since 2000.

Lake Simcoe's Cold-water Habitat…

Prior to European settlement, Lake Simcoe supported a strong, naturally-reproducing lake trout population and estimated late-summer dissolved oxygen concentrations were approximately 8 mg/L. These concentrations however declined to < 3 mg/L by the late 1980s, but have exceeded 5mg/L in most years since 2000.

Cold-water Community - Description of the Cold-water Fish and Invertebrate Community in Lake Simcoe

Over the past 10,000 years, since the last glacial retreat, the native cold-water fish and invertebrates of Lake Simcoe co-evolved as a well-integrated and interdependent community. Historically, the Lake Simcoe cold-water community included:

- Lake trout (*Salvelinus namaycush*) – a predator (piscivore), which exerts a very important role in maintenance of the structure of the fish community.
- Lake whitefish (*Coregonus clupeaformis*) – a medium-size benthivore dependent on the well being of small invertebrates living on the lake bottom.
- Lake herring (*Coregonus artedii*) – a small planktivore and primary prey of adult lake trout.
- Burbot (*Lota lota*) – a large predator that preys primarily on emerald shiner, yellow perch, lake herring, lake whitefish and occasionally on juvenile lake trout.


Lake Trout

- Slimy sculpin (*Cottus cognatus*) and spoonhead sculpin (*Cottus ricei*) – small benthivores that feed on small invertebrates and in turn are the preferred prey of juvenile lake trout.
- Several benthic invertebrate and zooplankton taxa including *Mysis relicta* (a rare glacial relict shrimp-like species).

Degraded Water Quality and a Changing Biological Community…

…land use changes, habitat loss, nutrient loading and species introductions altered Lake Simcoe's ecological conditions and functions and directly and indirectly affected the cold-water community.

Over the past century or more, numerous alterations to the Lake Simcoe ecosystem negatively affected water quality through land use changes, habitat loss and excessive nutrient loading. Biological changes to the fish community and food web dynamics through species introductions (e.g. rainbow smelt, black crappie, northern pike, spiny water flea, zebra mussel) also changed the lake's ecological conditions and functions and directly or indirectly affected the cold-water species. Relative to the 1800s to 1940s, extensive external P loading during the 1970s to 1990s (approximately 100 t/year) led to eutrophication and hypoxic conditions (low dissolved oxygen levels) in the deep waters of the lake during the summer, and to degradation of fish spawning areas in shallow waters (Evans et al. 1996). In recent decades, all of the primary cold-water fish species declined dramatically in abundance in Lake Simcoe: lake trout from the 1950s to 1970s, lake whitefish from the 1970s to 1980s and lake herring from the 1980s to 1990s. Several zooplankton species including two oligotrophic indicators (*Senecella calanoides* and *Limnocalanus macrurus*) were absent or scarce during the late 1980s and early 1990s and significant changes also occurred in the deep-water benthic invertebrate community. These changes indicate that impairment of the deep, cold-water habitat in Lake Simcoe had major effects on the native fish and invertebrate species (LSFAU 2004, Nicholls and Tudorancea 2001). At that time, the cold-water fish community was effectively placed on "life support". This came in the form of intensive regulatory efforts to reduce P and sediment loading combined with hatchery stocking programs to sustain the native stocks of lake trout and lake whitefish. Hatchery rearing and stocking, although definitely not preferred options for their management, have enabled the native lake trout and lake whitefish stocks to survive under seriously degraded conditions during the 1970s, 1980s and early 1990s.

… impairment of the deep, cold-water habitat in Lake Simcoe had major effects on the native fish… the cold-water fish community was effectively placed on "life support" during the early 1990s…

Assessment surveys during the 1960s indicated a gradual decline of lake trout. During that time lake trout were seen on spawning shoals, but very few young fish survived. Since the 1980s, wild lake trout have been virtually absent from the population and essentially all of the lake trout caught by anglers were hatchery-reared (LSFAU 2001). In 2001, two wild juvenile lake trout (recognized by lack of clipped fins that are applied to all hatchery fish) were captured in a deep-water trawling survey. However, since 2003 several more juveniles have been caught during various field surveys and wild adults between the ages of 2 and 8 have been caught in fall

Wild Lake Trout Survival…

…since the 1980s, wild lake trout have been virtually absent from Lake Simcoe's fish community. However, in 2001, two wild juvenile lake trout were captured, and since this time more wild juveniles and adults have been caught.

netting surveys and have also been increasingly reported by anglers (LSFAU 2006).

Natural recruitment of lake whitefish and lake herring populations has also occurred but to date only a single strong year class has been confirmed for each of these species (C. Willox, OMNR, personal communication). However, during the early 2000s lake herring was nearly absent. Catches of wild lake whitefish had become increasingly rare and the population was primarily composed of older wild fish or fish of hatchery origin. The occurrence of strong year classes for both lake herring and lake whitefish is a positive sign of improved environmental conditions. Rainbow smelt populations also declined sharply, but improved natural recruitment has recently been observed for this species as well. Similarly, the recent presence of *Mysis relicta* in the stomach contents of fishes is another indication of some recovery in the cold-water community.

Lake Trout Habitat – A Major Requirement to Sustain the Community

Cold-water fish have stringent DO requirements. This sensitivity to changes in water quality makes cold-water species excellent indicators of ecological health (Loftus and Reiger 1972). Lake trout, lake whitefish and lake herring suffered recruitment failure in the order of their sensitivity to hypolimnetic oxygen depletion in Lake Simcoe. The most sensitive of these cold-water fishes is the lake trout, which requires cold temperatures and well-oxygenated water throughout its life-cycle, especially during the young-of-year and juvenile stages and also during egg incubation.

…sensitivity to changes in water quality makes cold-water species excellent indicators of ecological health…

Temperature and Dissolved Oxygen Stratification

Temperature and oxygen operate as controlling and limiting factors that ultimately affect survival, growth, abundance and sustainability at the population level. Lake trout depend on cold, well-oxygenated water for long-term survival. Most daily activities can be achieved at 7 mg/L DO. Although higher DO levels are typically available in the surface waters (epilimnion), lake trout are generally blocked from these areas by high water temperature which they are unable to tolerate except for short periods of time. Lake trout typically seek thermal refuge in the cooler bottom waters (hypolimnion) of thermally stratified lakes during summer (Evans, 2007). During this time, an adequate supply of DO in these deep waters is essential to meet the metabolic demands of activities such as swimming, feeding, predator avoidance, and growth.

Lake Trout Survival

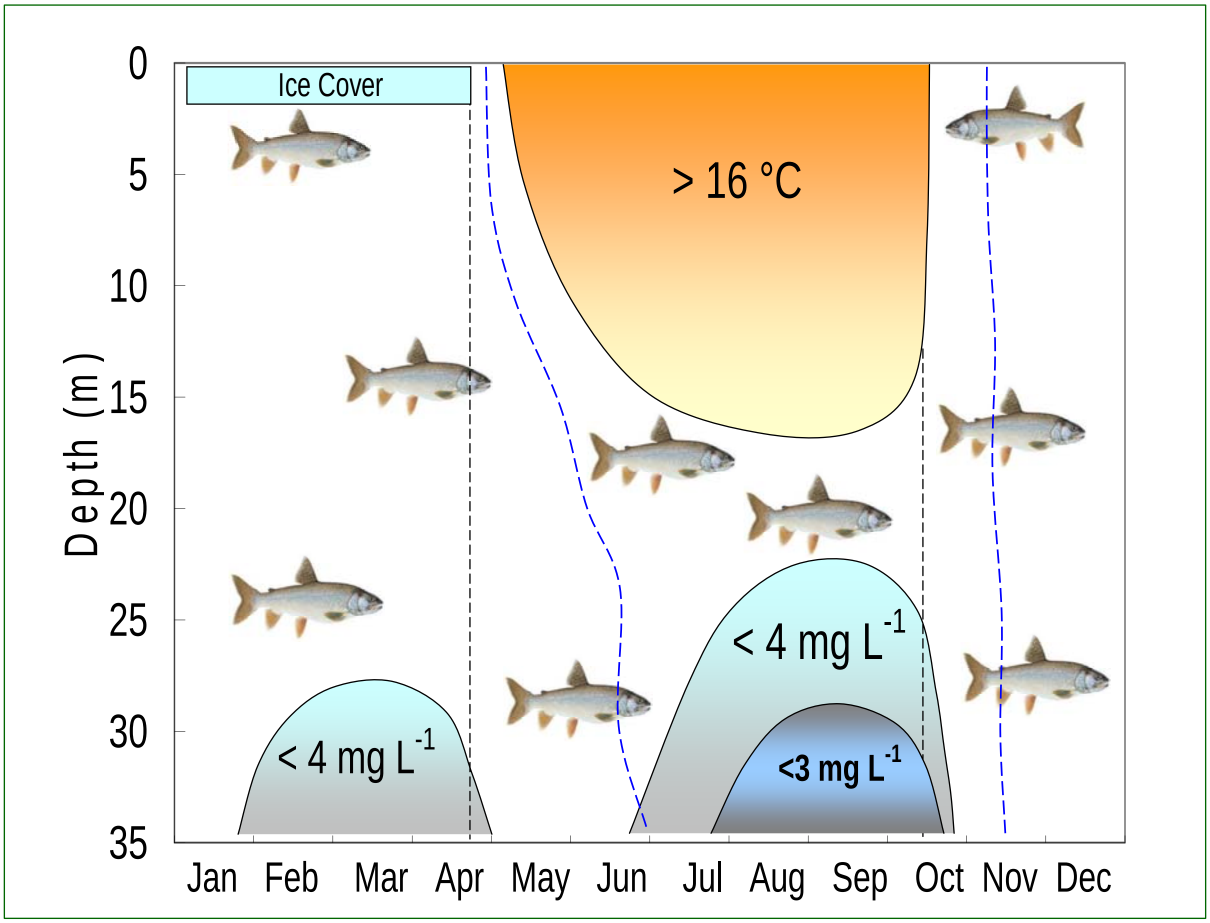
Lake trout depend on cold, well-oxygenated water for long-term survival. Lake trout typically seek refuge in the cooler deeper waters of Lake Simcoe during summer.

During the summer, an adequate supply of dissolved oxygen in these deep waters is essential to meet the metabolic demands of survival, i.e. swimming, feeding, predator avoidance, and growth.

…temperature and dissolved oxygen operate as controlling and limiting factors that ultimately affected survival, growth, abundance and sustainability of the lake trout population during the 1980s and 1990s and continue to do so…

During early summer, when surface waters begin to warm adult lake trout are usually found near the base of the thermocline, the transition zone between the warm surface layer and the cold bottom layer. As the season progresses and the thermocline deepens, adult lake trout generally move to even greater depths (Evans, 2007). Juveniles also show the same avoidance of warm surface water but must also avoid predation by the adults by staying still deeper in the water column. A study of lake trout distribution with respect to water temperature, DO, and light intensity in several small lakes in northwestern Ontario found that 75-90% of lake trout inhabited highly oxygenated water (>6 mg/L DO) throughout the spring and summer and that DO was the key factor determining lake trout vertical movement (Sellers et al. 1998).

Figure 3 - Illustration of the Habitat Squeeze Experienced by Lake Trout in Lake Simcoe During the 1980s and Early 1990s (courtesy of Dr. D.O. Evans, OMNR)



In Lake Simcoe, a general upward movement of lake trout in the water column occurs in response to declining DO levels (Evans 2007). The DO content of the deep waters of the hypolimnion in Lake Simcoe fell below the incipient lethal threshold of 3 mg/L for most of September during the 1980s and early 1990s. Under these conditions, juvenile lake trout can either move up in the water column into warmer temperatures where DO conditions are more favourable but predation risk is greater, or remain in the deep waters at suboptimal and

sometimes lethal conditions of temperature and oxygen. Consequently, a habitat limitation or "bottleneck" occurred in which the volume of suitable habitat (cold water with sufficient DO) was greatly reduced during late summer, when surface water temperatures exceeded 16°C (the upper thermal avoidance threshold) and DO in the bottom waters fell below 4 mg/L (the dissolved oxygen avoidance threshold). Under these conditions, lake trout are "squeezed" between temperatures above the thermocline that are too warm and bottom waters below the thermocline that may have inadequate DO, and may even be lethal depending on oxygen concentrations and exposure times.

Dissolved Oxygen Threshold of 7 mg/L

As DO concentrations are reduced, the ability to deliver oxygen to the blood declines and lake trout begin to suffer from hypoxia (insufficient oxygen). Hypoxia can occur as a result of natural changes to water quality during thermal stratification but may be accelerated by the consequences of excessive nutrient (e.g. P) inputs caused by human activities on the land. Hypoxia affects the metabolic "scope-for-activity", impairing growth and reproduction in lake trout (Gibson and Fry 1954, Evans 2007). At an ambient DO concentration of 7 mg/L, lake trout, especially at the juvenile life stage, experienced a 25 % reduction of scope-for-activity (which impairs the ability to perform work and compromises swimming ability, feeding, avoidance of predators, growth and survival). However, at this concentration most daily life support activities can still be completed and recruitment success does not appear to be significantly reduced. At DO concentrations of 5-6 mg/L recruitment of natural populations in inland lakes in southern Ontario was average to poor (Evans 2008). The lethal zone for juveniles is reached when DO levels drop below 3 mg/L, and if this threshold condition persists, extinction of populations would be expected (Evans, 2007).

Life Threatening Hypoxia…

…can occur as a result of natural changes to water quality during thermal stratification but may be accelerated by the consequences of excessive nutrient loads from human activities and land use changes.

Hypoxia affects the metabolic "scope-for-activity" which impairs growth, reproduction and other life-supporting activities in lake trout.

…extinction of the wild lake trout population would be expected if dissolved oxygen concentrations below 3 mg/L – the lethal threshold for lake trout juveniles – persisted in Lake Simcoe's deepwater…

A DO criterion of 7 mg/L (volume-weighted hypolimnetic) is now provincial policy for natural lake trout lakes on the Precambrian Shield. Lake trout lakes having late-summer DO at or below this criterion would have no further capacity for P loading without negatively affecting lake trout populations. Some lake trout lakes are naturally below this threshold because of their specific basin and watershed characteristics whereas others, such as Lake Simcoe, are below the threshold due to anthropogenic factors related to development and excessive nutrient loading. Lake trout populations inhabiting lakes that are below the threshold are also more vulnerable to other stressors including high fishing mortality, invading species and the effects of climate change, and therefore require special management attention (Evans, 2007).

Because the oxygen content of the hypolimnion declines throughout the summer during the period that the deep waters are isolated from the atmosphere, it is also critical to set a seasonal target date for the DO criterion. It is recommended that September 15 be recognized as the date to which the 7 mg/L criterion be applied. With regard to this date a

cautionary note is required because of the uncertain effects of climate change on conditions in the lake. If summer temperatures increase and the period of thermal stratification is extended, it will probably be necessary in the future to extend the critical date to September 30 or even later.

Statement of Goal:

The key requirement for the restoration of a naturally self-sustaining cold-water fish community in Lake Simcoe is that the deepwater DO levels meet or exceed the 7 mg/L criterion outlined above. Reductions in total P loadings to the lake will be necessary to meet this goal of suitable oxygen levels. How much reduction is needed and how this can be achieved are critical questions.

... native species have a strong inherent capacity for recovery once suitable environmental conditions have been achieved...

A Healthy Lake Trout Population

The key requirement for restoration of a naturally self-sustaining lake trout population in Lake Simcoe is that the deepwater dissolved oxygen levels meet or exceed the 7 mg/L criterion.

Current scientific evidence indicates that the cold-water fish community will not be restored unless the DO criterion is met. However, other factors probably contributed to the decline of the fishery including invasive species, the siltation of spawning shoals and persistent toxic contaminants (Houde et al 2008 in press, Guildford et al submitted describe contaminant accumulation in lake trout food webs). Mitigating the impact of these, and the other stressors acting on the lake outlined in Report 2, will be necessary to restore the native cold-water community and improve the health of the lake. The added uncertainty of climatic change (Guildford et al submitted) and the ongoing threat of new invading species to the cold-water fish community argue for quick action to restore healthy environmental conditions in which native species have the best possible prospects for survival. Our observation is that native species have a strong inherent capacity for recovery once suitable environmental conditions have been achieved. We believe that the modest return of natural reproduction that has been observed in several species during very recent years is an affirmation of this conclusion. It is critical to note, however, that given the multiple stressors acting on the coldwater fish community that we do not expect these modest improvements to be sustained without ongoing efforts to further protect and improve environmental conditions within the watershed.


Nearshore Netting Index

Q. 9 – What are the necessary spatial boundaries for the sustainable management of Lake Simcoe?

To manage the stressors impacting Lake Simcoe, the entire drainage basin needs to be included in the management plan. However, groundwater aquifers and the airshed also need to be considered, and these include areas that extend well beyond the boundary of the terrestrial watershed defined on the basis of surface water runoff.

Oro Township

The groundwater aquifers include portions of the Oro Moraine in the north, the Oak Ridges Moraine in the south, and extend to the old Algonquin Lake shoreline in the west. The Lake Simcoe airshed extends further, and encompasses the area from which airborne pollutants are transported and then deposited onto Lake Simcoe from local and long range sources even beyond Ontario's borders. From a management perspective, however, our emphasis will be on local sources of airborne pollutants within the watershed and nearby, including dust from agricultural areas, roads and construction sites. Initial research indicates that approximately 60% of the atmospheric P load may be generated from local sources (B. Gharabaghi, personal communication). These may be just beyond the watershed boundary and should be addressed in management initiatives e.g. implementing best management practices to reduce the loss of soil caused by wind erosion.

Areas outside the watershed along the western portion in particular will certainly have an impact on the health of Lake Simcoe. The boundaries of the watershed are particularly narrow along the western shore, an area subject to intensive development. For example, the sewers servicing portions of the cities of Barrie and Orillia may extend beyond the watershed boundary but still discharge into the lake. Management of lands and human activities beyond the watershed will also be needed to effectively protect important natural heritage features and their quality and size to minimize fragmentation and enhance connectivity.

Sustainable Management of Lake Simcoe

Management of lands and human activities beyond the watershed will also be needed to effectively protect important natural heritage features and their quality and size to minimize habitat fragmentation and enhance connectivity. Those areas of the ground water aquifer and airshed extending beyond the watershed boundary also need to be included in the management plan.

Restricting protection efforts to only the area within the watershed, therefore, will be an inadequate shield against stressors, particularly on the west side of the lake. Extended zones of protection should be based on atmospheric transport and ground water models, as well as on considerations for the appropriate protection of natural areas and habitats.

…restricting protection efforts only for the areas within the watershed will be an inadequate shield for Lake Simcoe against the stressors…

Mapping the Boundary Needs:

The following are suggestions to help establish an appropriate boundary:

1. Map the airshed – particularly define sources of atmospheric dust and P additions to the lake that are relatively local but outside the watershed boundary.
2. Determine the extent of the groundwater aquifer and appropriate protections in conjunction with the Source Water Protection Act and Oak Ridges Moraine Protection Act initiatives that are already under way.
3. Map human population growth trajectories and the area of different land use planning protection measures in place (e.g. Greenbelt Act).
4. Map natural areas to the edges of the watershed and incorporate extensions or buffers that extend beyond the watershed boundary to provide protection as necessary to maintain biodiversity and the integrity of terrestrial features and land cover that provides contiguous habitats.

Q. 10 – What approaches are required to mitigate the impact of the multiple stressors acting on Lake Simcoe?

Ecological Health of Lake Simcoe

...Lake Simcoe and its watershed have been subjected to, and subsequently altered by, a number of stressors for many decades, and its ecological health has been seriously impaired as a result.

The goal for the Lake Simcoe Protection Strategy is "to protect and restore the ecological health of the Lake Simcoe watershed ecosystem".

A healthy ecosystem is one where the ecological functions and processes can be considered to be acting within the "normal" limits of variation, that is, comparable to those that occurred historically in the same ecosystem, or that occur currently in a similar ecosystem that has not been degraded. Further, ecosystem health can be characterized by the capacity to absorb perturbations and rapidly resume normal activities (Callicott et al. 1999). Ecological functions and processes will occur in both natural (e.g. undisturbed wetlands or forests) and managed (e.g. reforested or agricultural) ecosystems, and the challenge is to restore the ecosystem health of the Lake Simcoe watershed while balancing the desire for local food production and places to live and work.

Lake Simcoe has been subjected to, and subsequently altered by, a number of stressors for many decades, and its ecological health has been seriously impaired as a result. Interim management practices have led to some improvements; for example, intervention through science, research and management initiatives have likely saved lake trout and possibly other members of the cold-water community from extinction. Agricultural abandonment over the past century has resulted in the recovery of some forest cover. However, the human population the watershed has grown and this growth is forecast to continue into the future. To ensure the long-term ecological health of the lake, and the associated health of its human communities, further reductions in the stressors that affect the lake and its watershed are essential.

In addition, there is considerable uncertainty about how Lake Simcoe will respond to future major environmental stressors, notably climate change and new invasive species. In combination with increased development and other changes in land use that are linked to a growing human population, the future of Lake Simcoe is cause for considerable concern and requires vigilance, innovation and bold new approaches.

All our recommended management approaches for dealing with the complexity of issues affecting the health of Lake Simcoe, its watershed and watershed residents, are based on the premise that healthy ecosystems that support self-sustaining, biologically diverse ecological communities provide maximal social and economic benefits to people by providing clean air and water, and renewable and useable resources that provide a support base for healthy, viable human communities.

…the future of Lake Simcoe is cause for considerable concern and requires vigilance, innovation and bold new approaches…

It is important to note that some of our recommendations are characterized by more uncertainty than others with regard to ensuring adequate prescriptions to address the stressors, the future trajectories of which are uncertain or unknown. This means that we cannot be sure that the actions listed here will be sufficient to counter the adverse impacts of the stressors, particularly when they act in concert and cause complex cumulative impacts. This makes it critical to monitor appropriate indicators of each stressor, and to put mechanisms in place that will enable course adjustments if targets are not met or when new information becomes available.

In what follows, we have reviewed the major stressors, identified management objectives and key targets to minimize impacts, improve and, where possible, restore the overall health of the Lake Simcoe ecosystem. This includes protecting its water and air quality, cold-water fish community, shorelines and aquatic habitats, groundwater systems, streams, river valleys and riparian zones, wetlands and forests in order to maintain the richness and diversity of native species. The sources of stressors have also been identified and recommended management approaches have been listed.

1. Objectives and Targets for the 8 Stressor Categories

Appropriate and measurable targets should be established for all eight stressors in order to provide a focus for management activities and land use decisions, and the effects of these activities should be carefully monitored to assess their effectiveness. A summary of the key stressors and associated objectives and targets are provided in Table 2 on page 61.

Stressor 1 – Nutrients

Nutrients (primarily P and N) are naturally found in the lake and watershed, and are a basic requirement for plant growth (primary production) which in turn drives the productivity of the entire aquatic ecosystem. Nutrient concentrations in the lake in the pre-industrial era can be considered as background levels that do not damage the ecosystem. The management of the anthropogenic post-industrial era nutrient inputs to Lake Simcoe has been primarily focused on sources of P because P is the primary nutrient most limiting plant and algal growth

in the lake. Nitrogen is found in many forms in the lake and the atmosphere, but rarely is the limiting nutrient in terms of plant growth in fresh water systems. At present, attempting to control N concentrations in order to control plant growth in Lake Simcoe is judged to be inappropriate. However, at very high concentrations not typically seen in Lake Simcoe or its inflowing rivers, some forms of N, notably ammonia and nitrate become toxic to organisms. Excessive N inputs to the watershed can also, via several microbial processes, lead to the emission of substantial quantities of the potent greenhouse gas, N_2O.

Algae Bloom

The most recent published data from LSEMS shows a decrease in annual P loads to the lake. There were decreasing trends in loads from the tributary portion (1990 to 2004) and STPs (1993 to 2004). The 6-year average total annual load from 1998-2004 was 67 ± 8 t/yr (mean ± standard deviation), a reduction from the more than 100 t/yr load estimated during the 1990s, and was below the LSEMS target level of 75 t/yr for most of the years. This is still well above the estimated background load of 32 t/yr, and continued reduction of total P loading is unlikely given some of the current land use and related trends listed in Report 2.

Objective 1

Nutrients – To reduce P loads to the lake to achieve a DO concentration of no less than 7 mg/L (mean weighted hypolimnetic DO) in the hypoliminion as of each September 15th to protect cold-water fish species.

- Minimum, late summer, mean weighted hypolimnetic DO (before September 15th).
- Applies to protection of cold-water community and improving the general health of the Lake.
- Oxygen is a fundamental requirement for living organisms. Concentrations <7 mg/L significantly reduce the health and vigour of lake trout.
- Recent analyses indicate that a total phosphorus loading rate of 44 t/yr will be required to achieve the 7 mg/L dissolved oxygen target (Nicholls 1997; Winter and Young, unpublished 2008).

Objective 2

Nutrients – To reduce P loads to the lake such that lake concentrations do not exceed 6 µg/L total P at spring overturn.

- This concentration is the estimated concentration that cannot be exceeded to maintain the 7 mg/L dissolved oxygen target, based on the Nicholls (1997) model.

- This is consistent with the PWQO of *10µg/L or less*, and should provide a high level of protection against aesthetic deterioration, including the excessive growth of algae and macrophytes.

Inappropriate practices…

…lead to harmful impacts

Stressor 2 - Pollutants

The other pollutants category includes the following:

- Suspended sediments
- Chloride
- Organic carbon
- Metals
- Organic chemicals
- Inorganic pesticides
- Pharmaceuticals

Of particular concern are contaminants that pose a potential health risk to humans consuming fish or drinking the water.

Objective 3

Pollutants – To ensure that levels of pollutants in the lake and its tributaries do not exceed the provincial (such as Provincial Water Quality Objectives, PWQOs and Provincial Sediment Quality Guidelines PSQGs) or federal criteria for surface waters and sediments, and to determine sources of pollutants and implement effective remediation measures where criteria (e.g. PWQOs and PSQGs) are not being met.

Provincial Water Quality Objectives are numerical criteria that serve as chemical and physical indicators representing a satisfactory level for lakes and rivers and, where it discharges to the surface, the ground water of the Province. The PWQOs are set at levels that protect all forms of aquatic life and all aspects of aquatic life cycles during indefinite exposure to the water. The Objectives for protection of recreational water uses are based on public health and aesthetic considerations. Provincial sediment quality guidelines are the primary tool for management of sediment quality in Ontario. They are based on the distribution of sediment-dwelling animals as a function of sediment contaminant concentration.

Objective 4

Pollutants – To strive to achieve contaminant levels in fish tissues that do not cause consumption restrictions in fish as published in the Guide to Eating Ontario Sport Fish*, and to ensure that long term trends in contaminant levels in fish tissues decrease.*

Objective 5

Pollutants – To monitor, report on, and address newly identified contaminants as analytical methods become available.

Stressor 3 - Pathogens

Waterborne pathogens (including bacteria and viruses) pose a potential health threat to humans. The presence of bacteria in excess of the PWQO for body-contact recreation is a direct threat to the health and the recreational experience of the people using the lake.

Objective 6

Pathogens – To have no beach closures as a result of pathogens.

Infectious diseases in wildlife - both those that are appearing in populations for the first time and those that are increasing in prevalence or range - are emerging worldwide at increasing frequency, and are often considered to be a symptom of rapid ecological change (Wobeser 2002). Examples in eastern North America include avian flu and West Nile virus in birds, chronic wasting disease in ungulates, amphibian chytridiomycosis and most recently, white-nosed syndrome involved in a massive die-off of several species of bats. Although the consequences of such outbreaks are variable and unpredictable, at their worst they can pose a substantial threat to biodiversity by incurring high mortality rates, or can function as pathogen reservoirs that threaten the health of humans and domestic animals.

Objective 7

Pathogens – To have heightened awareness among wildlife managers of emerging wildlife diseases in the region and monitor the health of wildlife where feasible.

Stressor 4 - Introduced Species

Many of the aquatic and terrestrial species within the Lake Simcoe ecosystem are not indigenous to the lake or the watershed. A number of recent invaders have caused significant and rapid changes to the Lake Simcoe ecosystem.

The aquatic introduced species known to be in the lake and watershed and their dates of introduction (where known) include:

- Common carp (*Cyprinus carpo*) – 1896
- Rainbow smelt (*Osmerus mordax*) – 1962

- Eurasian watermilfoil (*Myriophillum spicatum*) – 1984
- Curly-leaf pondweed (*Potamogeton crispus*)– 1961-1984
- Black crappie (*Pomoxis nigromaculatus*) – 1987
- Zebra mussel (*Dreissena polymorpha*) – early 1990s
- Spiny water flea (*Bythotrephes longimanus*) – 1993
- Bluegill (*Lepomis macrochirus*) – 2000
- Quagga mussel (*Dreissena bugensis*) – 2004
- Rusty crayfish (*Oronectes rusticus*) - 2004
- Round goby (*Neogobius melanostomus*) – 2006
- *Echinogammarus ischnus* – first recorded in 2005

Terrestrial invaders may indirectly affect water quality through their impact on watershed vegetation. Examples in the Lake Simcoe watershed include purple loosestrife, ornamental jewel weed, dog-strangling vine, and invasive species of earthworms known to drastically reduce the protective organic layer of vegetation in hardwood forests (Eisenhauer et al. 2007).

Objective 8

Introduced Species – To have no new invasive species introduced in the watershed.

Stressor 5 – Climate Change

Predictions based on climate change models indicate that significant changes from the historic patterns of climate and weather in Ontario will occur in the future, and are apparently already underway. Predicted changes include more frequent extreme weather events, resulting in both drought and flooding, more frequent occasions of high wind velocities, and changes to ice cover and snowfall patterns. Overall, temperature is expected to increase by up to 5º C over the next century (Aherne et al. 2007).

The expectation is that the impacts of climate change will accelerate in the foreseeable future. In the section on "Indicators", a number of trends are identified, but the effects of climate change are uncertain, particularly at the local level and the manner in which the lake will respond is not well understood. For example Guildford et al. (submitted) hypothesize based on a large latitudinal study of lake trout and organic contaminants in 23 North American lakes (including Lake Simcoe) that warming may exacerbate bioaccumulation of PCBs in lake trout because it restricts trout access to littoral areas of lakes where a high quality diet in the form of benthic invertebrates contributes to healthy growth rates.

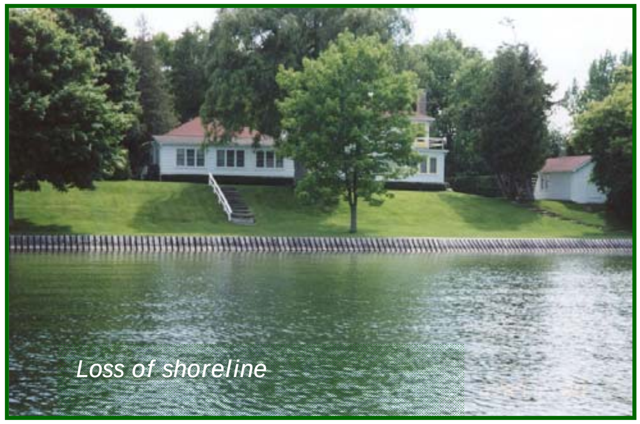
There are also linkages to the other stressors/threats, e.g., changes in ground water resources, increases in pathogens and disease; increase in wind and flood transport of

nutrients and contaminants, loss or change of species composition of woodland and wetland communities.

Objective 9

Climate Change – To include appropriate indicators as part of an integrated monitoring program in order to model the impact of climate change on Lake Simcoe and its watershed, explore opportunities for adaptation and develop an adaptation plan.

Stressor 6 – Land Use Change



Loss of shoreline

The ecosystem health of the watershed relies on the persistence of relatively intact natural areas, especially river valleys, wetlands, woodlands, and riparian zones along the shores of the lake and its tributaries. Protection of these areas from significant alteration, erosion and/or fragmentation is critical. For biodiversity, the evidence suggests a threshold amount of habitat loss beyond which even a small amount of change can shift the probability of extinction from near-zero to near-one (Fahrig 2001). Specifically, safeguarding such features of the watershed will serve to 1) provide well-connected habitats that facilitate movements of species vulnerable to human disturbance and aid in the maintenance of viable populations of sensitive species such as ground-nesting birds, amphibians, wetland species, and invertebrates; 2) ameliorate the ill effects on many species of “edge” environments, or the penetration of abiotic and biotic conditions characteristic of disturbed habitats on “interior” undisturbed habitats; and 3) in some cases protect provincially significant (irreplaceable) and rare ecological communities that occur in the Lake Simcoe watershed.

Progressive loss of wetlands (LSRCA)

Some unique features of natural heritage that have both provincial and local significance (e.g. rare plant communities, areas of natural and scientific interest, and wetland features) require

stringent, proactive protection. While the majority of the shoreline areas bordering the lake have been developed, there are still areas that remain in a relatively natural condition and the littoral zone is often relatively undisturbed along extended shoreline segments. The riparian and littoral zone components provide habitats for many terrestrial and aquatic species and contribute importantly to the overall biological and physical diversity of the lake and its tributaries.

A major concern in fragmented landscapes is the increased incidence of mesopredators that thrive in human-dominated landscapes such as mammals (raccoons, skunks, foxes, and feral cats), avian nest predators (blue jays and crows), and brood parasites (cowbirds), all of which concentrate their activities on the edges of forest. "Edge effects" also include abiotic conditions, ranging from windthrow (trees being uprooted by wind) to pedestrian and pet traffic. The extent to which these factors penetrate a habitat patch is highly species-dependent. The required size of intact habitat for persistence of wildlife populations that rely on them works in the same manner; generalizations about minimum critical size required, even for individual species, are still not possible. Planning should be guided by the needs of the most area-sensitive species, such as wide-ranging and interior-forest animals that rely on core interior habitat (Ray 2005), such as ovenbirds, red-eyed vireos, woodthrushes. scarlet tanagers, American redstarts, and pileated and hairy woodpeckers (Lee et al. 2002; Austen et al. 2001), wide-ranging carnivores, and amphibians (Gibbs 1998).

Objective 10

Land Use Change –To increase the percent cover of high-quality, intact habitat in the watershed and identify priority areas and targets at the sub-watershed level for re-naturalization

Objective 11

Land Use Change – To reduce fragmentation of natural areas by increasing the size of adjacent fragments and maintain existing naturalized areas in intact and connected states to prevent the loss of aquatic and terrestrial habitat in the watershed.

Objective 12

Land Use Change – To allow no further removal of wetland areas or features to protect the quality, function and extent of highly sensitive wetland habitats.

Objective 13

Land Use Change – To increase the naturalized areas along all shorelines, all wetlands, and all other provincially and locally significant natural areas and provide appropriate buffers along shorelines, intact forest habitats and wetlands to protect aquatic and terrestrial values from edge influences.

Objective 14

Land Use Change – To use green technology and BMPs in the watershed to increase infiltration and evapotranspiration of storm-water to reduce runoff and erosional losses to the tributaries and lake.

Best management practices to increase infiltration and evapotranspiration are outlined in the U.S. EPA's National Menu of Storm-water Best Management Practices http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm and include land grading, preserving natural vegetation, rain gardens, dust control, vegetated filter strips, grass-lined channels, on-lot treatment, wet ponds, temporary stream crossings, green roof and parking, infrastructure planning, urban forestry, and many more.

Stressor 7 – Water Extraction

Extraction of large amounts of groundwater and surface water (individually or cumulatively) may cause changes to the hydrological cycle, such as reducing base flow to streams, lowering of the water table, and reduced overall inflow of water to the lake. Climate change may exacerbate these impacts through changes in supply and increased evapotranspiration.

From the compiled water balance data, the main issue to date is maintaining base flow in the tributaries (e.g., the Maskinonge River and Whites Creeks; LSEMS 2008).

Objective 15

Water Extraction – To ensure that local water extraction is within sustainable thresholds through a comprehensive water budget analysis (ground and surface waters) in collaboration with the Source Water Protection process.

Objective 16

Water Extraction – To reduce water demand and consumption to an acceptable, sustainable level through the adoption of conservation measures, e.g., reuse and recycle water effluent via double pumping to new development.

Stressor 8 – Other Human Pressures

There are many other human uses of the watershed in addition to land use changes that constitute stressors to the lake including:

- Recreational uses, notably boating and fishing.
- Management regimes, including fish harvest and stocking.

Objective 17

Other Human Pressures – To ensure that extraction levels of aggregates and other natural resources and associated human activities in the lake and watershed are kept within limits of sustainability based on the best available science.

Objective 18

Other Human Pressures – To ensure that fish stocking is employed only to maintain threatened stocks or to restore severely depleted stocks and not to simply supplement stocks that have the potential for full recovery to self-sustaining status. Stocking should not be used where there is a high risk that stocked fish will cause excessive exploitation or predation pressure, or suppression of natural recruitment to the wild component of their own species or to other species.

2. Approaches to Mitigate Sources of Lake Simcoe Stressors

The ecological health of Lake Simcoe is directly connected to the health of its watershed and to factors beyond its boundaries through the atmosphere, through the sub-surface components of the hydrological cycle, and through direct connections between terrestrial and aquatic habitats. Human activities, including increased mobility of human populations that facilitate the introduction of exotic species, and land use changes that ultimately result in changes to effluent discharge from sewage treatment plants (STPs), septic tanks, storm-water runoff, agricultural runoff, and erosion of exposed soils by wind and water, have altered the natural cycling processes of nutrients and other chemical components within the aquatic and terrestrial environments. The current ecological state is highly vulnerable because of growing pressures on the watershed.

The following section addresses approaches to mitigate the eight primary stressors. For nutrients and other pollutants this is through reference to their sources, while invasive species, loss of natural areas and water extraction are considered specifically.

…the ecological health of Lake Simcoe is directly connected to the health of its watershed and to factors beyond its watershed boundary – atmosphere, groundwater and natural areas…

Table 2 - Key Objectives and Targets for the 8 Stressor Categories

STRESSORS	KEY OBJECTIVES AND TARGETS
Nutrients	1. To reduce P loads to the lake to achieve a DO concentration of no less than 7 mg/L (mean weighted hypolimnetic DO) in the hypoliminion as of each September 15th to protect cold-water fish species. 2. To reduce P loads to the lake such that lake concentrations do not exceed 6 µg/L total P at spring over turn.
Other Pollutants	3. To ensure that levels of pollutants in the lake and its tributaries do not exceed the provincial (such as Provincial Water Quality Objectives, PWQOs and Provincial Sediment Quality Guidelines PSQGs) or federal criteria for surface waters and sediments, and to determine sources of pollutants and implement effective remediation measures where criteria (e.g. PWQOs and PSQGs) are not being met. 4. To strive to achieve contaminant levels in fish tissues that do not cause consumption restrictions in fish as published in the *Guide to Eating Ontario Sport Fish*, and to ensure that long term trends in contaminant levels in fish tissues decrease. 5. To monitor, report on and address newly identified contaminants as analytical methods become available.
Pathogens	6. To have no beach closures as a result of pathogens. 7. To have heightened awareness among wildlife managers of emerging wildlife diseases in the region and monitor the health of wildlife where feasible.
Introduced Species	8. To have no new invasive species introduced in the watershed.
Climate Change	9. To include appropriate indicators as part of an integrated monitoring program in order to model the impact of climate change on Lake Simcoe and its watershed, explore opportunities for adaptation and develop an adaptation.
Land Use Change	10. To increase the percent cover of high-quality, intact habitat in the watershed and identify priority areas and targets at the sub-watershed level for re-naturalization. 11. To reduce fragmentation of natural areas by increasing the size of adjacent fragments and maintain existing naturalized areas in intact and connected states to prevent the loss of aquatic and terrestrial habitat in the watershed. 12. To allow no further removal of wetland areas or features to protect the quality, function and extent of highly sensitive wetland habitats. 13. To increase the naturalized areas along all shorelines, all wetlands, and all other provincially and locally significant natural areas and provide appropriate buffers along shorelines, intact forest habitats and wetlands to protect aquatic and terrestrial values from edge influences. 14. To use green technology and BMPs in the watershed to increase infiltration and evapotranspiration of storm-water to reduce runoff and erosional losses to the tributaries and lake.
Water Extraction	15. To ensure that local water extraction is within sustainable thresholds through a comprehensive water budget analysis (ground and surface waters) in collaboration with the Source Water Protection process. 16. To reduce water demand and consumption to an acceptable, sustainable level through the adoption of conservation measures, e.g., reuse and recycle water effluent via double pumping to new development.

Table 2 - Key Objectives and Targets for the 8 Stressor Categories

STRESSORS	KEY OBJECTIVES AND TARGETS
Other Human Pressures	17. To ensure that extraction levels of aggregates and other natural resources and associated human activities in the lake and watershed are kept within limits of sustainability based on the best available science. 18. To ensure that fish stocking is employed only to maintain threatened stocks or to restore severely depleted stocks and not to simply supplement stocks that have the potential for full recovery to self-sustaining status. Stocking should not be used where there is a high risk that stocked fish will cause excessive exploitation or predation pressure, or suppression of natural recruitment to the wild component of their own species or to other species.

2.1 General

The following recommendations apply to all sources of P and other pollutants:

Address general information gaps:

- *Develop a checklist of recommended best management practices for different land uses that can be used by agencies to grade each operation.*
- *Assess the contribution of external organic material loads to lake metabolism (e.g. lake oxygen levels) is required.*
- *Determine nature (e.g. solubility, availability and sources) of P entering surface waters.*
- *Monitor P storage capacity in the lake's sediments (littoral and pelagic).*
- *Monitor P movement through the ecosystem and internal P loading contribution to P loads, i.e., internal P cycle dynamics, including the role of dreissenid mussel filtering. Phosphorus in the sediments may diffuse into overlying water when DO is depleted. By effectively managing the watershed P loads, DO over the sediments should increase which will limit this internal loading of P from sediments.*

Recommendation 1

General – Develop total P targets for the three Lake Simcoe basins and the sub-watersheds:

a) Kempenfelt Bay – key deep water habitat for juvenile lake trout;
b) Cook's Bay – excessive macrophyte growth;
c) Main Basin – primary habitat for most native fish species;
d) Sub-watersheds – refine the analysis of sub-watershed contributions of P from all sources and incorporate with revised lake and basin targets to update sub-watershed targets.

- The loads to these three basins are not uniform, but each basin should have to achieve the same water quality targets.
- Existing P loading sources should also be challenged to minimize their TP contribution to the sub-watersheds and each bay.

Recommendation 2

***General –** No new or expanded development or site alteration and mandatory vegetated buffer zones along the lake shoreline and all watercourses are recommended throughout the watershed as follows:*

- o *within 100 m of undeveloped Lake Simcoe shoreline, and other shorelines in the watershed known to serve connectivity functions, coldwater or headwater streams, or other riparian zones requiring enhanced water quality protection,*
- o *within 30 m along other parts of the Lake Simcoe shoreline and other intermittent or perennial water courses in the watershed,*
- o *in those intensively developed areas (e.g. urban, agricultural and recreational) where a 30 m zone is not feasible, rehabilitate shorelines of the lake and its watershed to at least 15 m by restoring native vegetation where ever possible and avoiding the use of chemicals (e.g. fertilizers, pesticides),*
- o *no new shoreline developments or shoreline activities on land or in the water that disrupt natural shoreline processes or that otherwise damage riparian or littoral zone habitats.*

- A buffer strip is vegetated land (ideally comprised of native species) adjacent to water bodies that protect receiving waters (measured from the high water mark for lakes or the top of the bank for streams) and are positioned between aquatic habitat and terrestrial landscapes that have been altered by humans.
- These zones serve multiple functions, including: slowing the velocity of surface runoff, allowing infiltration and filtering runoff and associated nutrients and other pollutants, stabilizing shorelines from erosion, conserving habitats for the disproportionately high number of aquatic and terrestrial species that rely on these environments, regulating temperature and microclimate, screening noise and wind damage, and preserving the aesthetic appeal of the landscape.
- If tall enough to shade the water surface for example, riparian vegetation can reduce maximum temperatures of streams allowing survival of cold-water species such as brook trout. If wide enough, vegetated buffers provide important habitat for myriad species and function to connect habitats of area-sensitive and/or wide-ranging sensitive species (Hanowski et al. 2002, Sparovek et al. 2002). They provide the additional advantage of improving the viewscape and associated recreational benefits.
- In general, buffer width requirements vary according to the function they serve. Nutrient and sediment removal and temperature control can be achieved with narrower bands of vegetation to protect streams, but wider buffers are required to provide effective wildlife habitats and movement corridors (ELI 2003). In general buffer widths recommended for protection of terrestrial riparian components tend to be wider than those recommended for aquatic components. The minimum necessary width is also influenced by slope, soil and vegetation characteristics

(infiltration rate and porosity), and localized loading impacts (Castelle et al. 1994; Frimpong et al. 2005).

- Generally, a naturally vegetated buffer of 30 m will reduce nutrients and sediments reaching the water, but corridors should be at least 100 m wide for the purposes of conserving habitats for native biodiversity and further protecting water quality (ELI 2003).
- Most studies have consistently demonstrated that 100 m is required to provide sufficient breeding habitat for species such as birds of prey (Mitchell 1996), breeding Neotropical migrants (Mitchell 1996; Mason J, Moorman C, Hess G, Sinclair K. 2007), and amphibians (Semlitsch, R.D. 2000).
- Even wider buffer zones >500 m are necessary to maintain complete faunal communities (Kilgo et al. 1998; Burbrink et al. 1998).
- Connectivity between the natural areas within the watershed and adjacent areas outside is critical for the conservation of animal populations, with riparian zones naturally serving such a function.
- These corridors should be large enough to buffer the effects of adjacent land uses and allow the connectivity of core habitats. The more abrupt the transition from natural to modified habitat, and the more intensive the development within the latter, the wider the buffer needs to be.
- To ensure that buffers serve their purpose, development should not take place within these zones, and all sources of disturbance and contamination should be excluded (ELI 2003).
- When options for re-vegetation of adequate-sized buffers are limited or precluded, restoration should focus on eliminating harmful inputs into aquatic habitats within at least a 15m band. Restoration efforts should be prioritized based on the targets for each sub-watershed and the effectiveness of the restoration project on improving water quality.
- Innovative technologies and approaches should be encouraged to ensure that all watercourses are protected.

Recommendation 3

General – Provide incentives for the creation of larger buffer strips in sensitive areas to protect aquatic features and functions.

- Some aquatic areas are inherently more sensitive, pristine, or highly-valued and require a wider buffer. These might include headwater streams and floodplains.
- Buffers may need to be wider in some areas depending on local physical features of the landscape, i.e., steep slopes, floodplains, permeable soils, and proximity to key natural heritage features requiring connectivity corridors (see recommendation 36).
- For example, in areas with steep slopes, easily eroded soils, increased impervious surfaces resulting in high runoff, and for first order streams, larger buffers are

required from the top of stream bank in order to protect the quality of in-stream habitat and to facilitate normal riparian functions.

- Retention of undeveloped shoreline and restoration of altered shorelines will provide aesthetic value (improved viewscape) and will improve ecological function and provide important wildlife habitat and corridors, enhancing natural diversity.

2.2 Sewage Treatment Plants

The following are recommended approaches to reduce inputs from STPs to the lake and its tributaries:

Recommendation 4

Sewage Treatment Plants – Limit total P loads discharged from all STPs to the current annual load i.e. no increases above current loads to the lake.

- Lower the aggregate legal loading limit for all sewage treatment plants in the watershed.

Recommendation 5

Sewage Treatment Plants – Integrate the best available technology during STP expansions to meet new total P loading limits and improve removal of other pollutants.

- Will help to achieve the load cap and TP concentration target.
- New expansions would have to operate under the new load limit.

Recommendation 6

Sewage Treatment Plants – Implement an incentive program for under-shooting P caps.

Recommendation 7

Sewage Treatment Plants – Consider interim provincial regulations to ban phosphates in dishwasher detergents until the federal plan is in effect (currently proposed for 2010).

Recommendation 8

Sewage Treatment Plants – Monitor pharmaceutical contamination by collecting effluent samples from all STPs in the watershed to develop targets for the receiving waters, and enforce treatment changes to meet targets.

- There are global concerns regarding the dangers of ingesting pharmaceuticals from drinking water.

Recommendation 9

Sewage Treatment Plants – Use the best commercially available technology and/or management strategies for all STP expansions and upgrades with the objective of removing pharmaceuticals altogether.

- Current scientific research suggests that the use of an advanced oxidation procedures can potentially greatly reduce the concentration of pharmaceutical contaminants in the water.
- Future needs include recommending proven technologies and BMPs that best reduce or remove pharmaceuticals. Apply zero tolerance of pharmaceuticals as technology is made available.

Recommendation 10

Sewage Treatment Plants – Investigate options for use of current effluents for other purposes, e.g., irrigation of sod farms, golf courses, etc. Move to zero effluent discharge from sewage treatment facilities and provide incentives for doing so.

2.3 Storm-water Sources

The following are recommended approaches to mitigate P loads, pathogens, contaminants and sediments from storm-water sewers and runoff to the lake and its tributaries.

Recommendation 11

Storm-water Sources – Decrease P loads from urban storm-water runoff below current levels.

- Annual P loads from urban non-point sources running off directly into the lake were estimated at 9 t/yr from 1998 to 2004. Recent estimates by the LSRCA (2007) indicate that the total storm-water loads to the lake from all existing urban areas in the watershed could be as high as 23 t/yr.
- Loads from urban non-point sources clearly need to be reduced. For example, municipalities could be required to implement storm-water retro-fit programs and storm-water standards for new development could be made more stringent.

Recommendation 12

Storm-water Sources – Endorse green technology and smart growth management plans that encourage permeable development strategies and off-setting to reduce flow into storm-water control systems.

- Green roof programs should be explored
- Tax incentives for the use of permeable pavement should be made available

- Leadership in Energy and Environmental Design (LEED) programs should be explored (see recommendation 26)
- Future growth should be directed to existing settlement areas; this will reduce future storm-water flows if there is no increase in impervious area associated with infill development
- Low impact development design tools should be explored.

Recommendation 13

Storm-water Sources – Set maximum impervious surface targets (% cover) for the watershed and sub-watersheds.

- Determine and set targets for the watershed and each sub-watershed. Less than 10 percent imperviousness (paved surfaces) in an urbanized watershed is required to maintain stream water quality and quantity, although some species shows signs of stress and population decline before the 10% impervious cover level is reached. In general, however, aquatic biological systems begin to degrade at impervious levels of 10-15% (Arnold and Gibbons 1996, Booth and Jackson 1997).
- Innovative designs promoting ground infiltration of runoff are required in the Lake Simcoe watershed (http://nemo.uconn.edu/tools/impervious_surfaces/index.htm).
- Information should be compiled on how much permeable pavement/concrete has been installed each year. This would provide an indicator showing progress in reducing urban storm-water run-off.
- The overall goal should be to avoid extreme peak flows by incrementally minimizing hard surfaces and disconnecting roof downspouts from storm-water drains.

Recommendation 14

Storm -water Sources – Storm-water management must include retrofitting or constructing new infrastructure, especially in areas where no storm-water facilities existed before.

- Need to control the volume of storm-water pre- and post development **to achieve no net change**.
- Enforcement of the use of storm-water ponds, or other control structures, and their maintenance.
- Retrofit includes the creation or modification of an urban runoff management system, e.g., wet ponds, infiltration systems, wetland plantings, stream bank stabilization, and other best management practices for improving water quality
- Technological and engineering solutions are required to control cumulative additions of suspended and dissolved solids and pollutants (e.g. chloride, metals) to storm-water, ground water and surface waters from urban areas.

2.4 **Agriculture**

The following are recommended approaches to mitigate P loads, sediments, pathogens and contaminants from agricultural lands to the lake and its tributaries. The SciAC recognized the environmental and social benefits of local food production. Therefore management actions should incorporate appropriate incentives and compensation to counter losses in revenue incurred by farmers.

Address information gaps:

- *An inventory of sources of P loading to surface water for each sub-watershed to focus management efforts on voluntary versus mandatory controls is needed.*
- *An analysis of the effectiveness of vegetative buffers is needed for different types of buffers (e.g., type of vegetation, width) associated with different agricultural practices and topographies (e.g. slope). This should include an in-depth literature review as well as Lake Simcoe-specific field studies and would be reconciled with requirements for buffer widths required to maintain other values in the watershed. For example, tile drainage can reduce the effectiveness of nutrient removal from shallow groundwater and can increase inputs of fine sediments (Barton 1996, Spaling 1995, Stone and Krishnappan 1997, 2002).*
- *Further research is required to assess the impact of various agricultural best management practices on differences between soluble and particulate P leaving the field and the potential impacts on the lake and its tributaries.*
- *Research is required to effectively identify seasonal and spatial variations in areas contributing to runoff from exiting farm fields and the concentrated flow paths that this runoff follows. This is urgent need to identify effective buffer strip locations and widths, as well as where additional mitigation practices (e.g. no-till, nutrient input reduction etc.) are required within the field to reduce sediment, pathogen and nutrient transport to watercourses.*
- *In polder areas, the following specific information needs include:*
  - *Characterize the nature of muck soils in the polder areas e.g. P sorption characteristics.*
  - *Update crop recommendations for fertilizer applications.*
  - *Evaluate best management practices to reduce P losses to surface water for use in polder areas, including treatment of drainage water.*
  - *Develop polder-specific communication materials and strategies.*

Recommendation 15

Agriculture – Continue the implementation of good farming practices and best management practices in the watershed based on the local conditions of the land through the Nutrient Management Act and Environmental Farm Planning process to address concerns about nutrient and contaminant inputs and soil loss.

- Risk assessment of management strategies applied at the property level and its contribution to the achievement of watershed-scale targets, e.g., sub-watershed specific goals, is needed.
- Coordination and integration of property level strategies will be necessary to achieve the over-arching sub-watershed-level goals, e.g., if each farm implements appropriate best management practices, the overall benefits will be greater than with each farm implementing individual non-coordinated strategies.

Recommendation 16

Agriculture – All farms (small and large) in the watershed should implement a nutrient management plan (NMP).

- A NMP details how nutrients are to be applied to a given land base. The plan is based on both the components of the nutrients used and the characteristics of the field, and optimizes the utilization of the nutrients by crops in the field and minimizes environmental impacts.

Recommendation 17

Agriculture – No new expansion or development of farms into existing natural areas.

Recommendation 18

Agriculture – Avoid application of nutrients on frozen or snow-covered ground.

- During spring freshet when the snow melts and grounds defrost any nutrients applied over winter run the risk of being washed into adjacent water-bodies or leached into the ground water from melting snow and ice.
- However, application of manures to frozen or snow-covered ground may represent a rational alternative (i.e. a reasonable contingency plan) for instances when proper manure storage capacity is reached and when field/soil conditions at the planned time of manure application were such that material loss and damage to soil quality were likely to have been excessive.

Recommendation 19

Agriculture – Exclusion of livestock from all watercourses.

- Fencing riparian buffers would minimize in-stream disturbance, reduce nutrient and sediment loads, and contribute to source water protection and the protection of local biodiversity.

Recommendation 20

Agriculture – Implement erosion control incentives to encourage the participation of all farms in the watershed to minimize erosion of exposed soils (by wind and water) and P loading to the lake.

Recommendation 21

Agriculture – Monitor the impacts of the implementation of recommended best management practices on agricultural land to determine if particular sub-watersheds would need additional controls on the variety and spatial extent of agricultural uses, farm location, livestock density or farming intensification to meet the levels of P inputs that the lake can sustain.

- Matching the nutrient applications on a farm to the crop requirements though a NMP would be a positive step towards reducing nutrient losses from individual farm fields. These plans do not, however, identify areas with the greatest load potential due to farming intensity or other activities. Farms in certain sub-watersheds may require additional management measures to achieve acceptable nutrient loads to nearby watercourses. We will need to identify whether there are sub-watersheds where all farms are following NMP, but nutrient loadings are still above target values.

Recommendation 22

Agriculture – Develop a voluntary certification program for green farming practices throughout the watershed (e.g., similar principles applied with the voluntary Environmental Farm Plan).

Recommendation 23

Agriculture – Develop best management practices for tile drains to minimize losses of nutrients, sediment and water.

2.5 **Construction Sites**

The following are recommended approaches to mitigate the impacts of erosion, loss of natural areas, and increased storm-water runoff attributed to construction sites to reduce phosphorus loads and sediments to the lake and its tributaries:

Recommendation 24

Construction Sites – Review existing construction guidelines in Ontario to ensure their sufficiency to reduce the erosion losses of exposed soils off-site and overall P loads to the lake and its inflowing watercourses.

- Review control measures outlined e.g., straw barriers, site fencing, soil covers, etc to reduce runoff from sites.
- Review both in terms of enforcement and long-term maintenance.
- Develop specific strategies to minimize erosion losses from construction sites in the Lake Simcoe watershed as necessary.

Recommendation 25

Construction Sites – Implement and maintain wind erosion mitigating efforts at all construction sites to reduce P and sediment loads to the lake and its tributaries in order to minimize the impacts from atmospheric deposition, e.g., cover exposed soils, plant or erect wind breaks, and use non-toxic based dust suppressants.

Recommendation 26

Construction Sites – Encourage all municipalities to adopt green building certification programs, such as the Leadership in Energy and Environmental Design (LEED) and Minnesota GreenStar Systems certification program.

- The LEED Canada green building rating system encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria (www.cagbc.org).
- LEED Canada is an adaptation of the US Green Building Council's LEED, a third party certification program and nationally accepted benchmark for the design, construction and operation of high-performance green buildings so they are appropriate for Canadian climates, construction practices and regulations.
- LEED certifies construction sites, e.g., amount of vehicle use, tire washing to reduce movement of soil off site, etc.
- Companies go through a voluntary process similar to the Environmental Farm Planning process to implement green technology and materials during both the design and construction phase.
- LEED works at the site level for dust control, but does not specifically target wind erosion.

2.6 **Septic Systems**

The following are recommended approaches to mitigate P loads and pathogens from septic systems to the lake and its tributaries:

Address information gaps:

- *Study potential for nutrient and pathogen contamination of water associated with lack of septic system maintenance, with different types of septic system technology, soil type and physical constraints of the landscape etc.*
- *Determine relative risks associated with municipal servicing versus septic system use in terms of impacts on water quality. For example, servicing provides for treatment of sewage but might encourage more intensive development in a sensitive area.*
- *Research new technology for retaining P and develop a list of MOE-approved technologies. Avoid technologies that add iron because, in the event that it leaches*

into the lake, it may stimulate the growth of cyanobacteria (blue-green algae) and negatively impact water quality (Molot 2008).

Recommendation 27

Septic Systems – The ultimate objective is to provide new development and redevelopment incentives to phase out septic systems completely or to upgrade to on-site sewage treatment systems that will completely eliminate P loading where applicable. In the interim, revitalize the Septic System Re-inspection Program and provide recommendations for upgrades.

Recommendation 28

Septic Systems – Provide financial incentives to encourage property owners to upgrade systems and use best available technology (MOE approved).

- Most property owners cannot afford new septic systems or upgrades which can cost $10,000 to $30,000 depending on the technology and the physical restrictions of the land (i.e., soil depth, topography, etc.); therefore, subsidizing costs may encourage more participation.
- For example, the Lake Simcoe Water Quality Improvement Program is currently offered through a partnership between the Lake Simcoe Region Conservation Authority, its member municipalities, and the York, Durham and Simcoe chapters of the Ontario Federation of Agriculture, and offers a 50 % funding rate for upgrading private septic system up to a cap of $2500 (http://www.lsrca.on.ca/lswqip).

Recommendation 29

Septic Systems – Promote regular maintenance of septic systems through pump outs every 3 to 5 years for systems greater than 10 years of age to improve the efficiency of the system to minimize nutrient and pathogen loading to the lake.

2.7 **Atmospheric Deposition**

The following are recommended approaches to mitigate particulate and P loads to the lake from short range atmospheric sources:

Address information gaps:

- *Identify all atmospheric sources contributing P loads to the lake including long range sources. Partition the sources so that mitigation can be targeted appropriately.*
- *Assess the impacts from various activities/land use including:*
    - *Practices on construction sites, rock quarries and farms that promote soil erosion by wind.*
    - *Temporal variability of the land use activities and associated wind erosion and deposition.*
    - *Estimation of background P concentration from undisturbed areas.*

- *Contribution of distant sources versus local sources.*
- *Linkages and comparative analysis of P loading contribution from various activities to the atmospheric deposition in order to better predict the effectiveness of tradeoffs and meeting targets within the watershed.*

- *Determine the effects of zero tolerance from new development, including enforcement, and implementing a moratorium until existing sources improve their contribution.*
- *Identify all atmospheric sources contributing P loads to the lake, including long-range sources.*
- *Study the effects of degrading air quality (i.e., increase of smog alerts and respiratory diseases within the watershed) on species and their habitats, as well as the impacts to human health.*
- *Intensify monitoring efforts by creating more lake-based stations.*

Recommendation 30

Atmospheric Deposition – Implement the use of windbreaks and shelter belts in the watershed, including along the lake's shoreline.

- Research is underway to determine the amount of atmospheric P deposited on the lake that is derived from local sources and to target appropriate management actions. However, initial estimates indicate that the local contribution is substantial and efforts should be made to reduce this load where possible.
- Herbaceous wind barriers break the wind's length of travel across fields and reduce the amount of particulate material entrained. This is of particular concern on construction sites, and in field and cropping systems where the soil surface may be bare and susceptible to wind erosion during long periods of the growing season. Recommended plants include trees, maize, sorghum, sunflowers, and tall wheatgrass.
- Snow fence and windbreaks – a large proportion of the sediment/particulate material entrained in the air column is in close proximity to the ground. Rows of tall trees may be planted perpendicular to the prevailing wind direction to reduce transport and encourage deposition of materials suspended in the air (e.g. trees could be planted along both sides of major north-south highways to effectively reduce atmospheric loads from highways).
- The protection of natural areas will aid in blocking the transport of particulate material to the lake.

Recommendation 31

Atmospheric Deposition – Non-toxic dust suppression and soil stabilization are recommended at all active construction sites, aggregate mining, and unpaved roads.

Recommendation 32

Atmospheric Deposition – Surface roughening, cover crops and conservation tillage systems are recommended for farmers to reduce wind erosion.

- Maintaining 60% ground cover may reduce wind erosion by more than 80% (Zhang et al. 2004).
- Conservation tillage and cross-wind ridges increase the roughness of the soil surface and may reduce wind erosion by about 25% (USDA, 2002).

2.8 Introduced Species

The following are recommended approaches to prevent, or at least minimize, the introduction of new introduced species into the watershed to investigate their impacts:

Recommendation 33

Introduced Species – Investigate, with the use of critical monitoring, how invasive species enter the system and their impacts on the lake and its watershed to determine future options for management.

- Once an invasive species establishes a breeding population, it is difficult to manage or eradicate.
- The impacts of new introductions are often unpredictable.
- To improve the resilience of the lake ecosystem to invasive species, the best strategy is to implement management initiatives that target other stressors, such as reducing P loading or protecting shorelines and intact natural areas from development, to enhance the capacity of native species to sustain strong populations.

Recommendation 34

Introduced Species –Coordinate and implement measures (education and regulations) that prevent additional invasive species from entering the lake and watershed to meet the "no new invasive species" watershed target. Work with federal and provincial agencies such as the International Joint Commission, the Great Lakes Fisheries Commission, and the Canada-Ontario Agreement (COA).

- Eliminate the introduction of non-native species by baitfish harvesters/vendors (off-line ponds), and via navigation canals, ornamental ponds (fish and plants) and aquariums.
- Manage movement of fish and boats into the system, including inspecting live wells on boats and building awareness, e.g., Ontario Federation of Anglers and Hunters and Ontario Baitfish Association educational materials. Boaters should be required to drain all live wells prior to entry into and passage through the Trent Severn Waterway and random inspection should be implemented at all lock stations.

- Manage movement of terrestrial plants and insects into the watershed by building awareness.
- Ban the import of live bait fish and aquatic invertebrates to the lake and its tributaries from outside the watershed to minimize disease transport or the introduction of non-native species. Future consideration could be to phase-in a ban on all use of live bait.
- Ban the export of live bait from Lake Simcoe to all other watersheds to prevent Lake Simcoe from acting as a vector for the spread of invasive species and aquatic diseases to other lakes and watersheds in Ontario.
- Efforts to prevent introductions to Lake Simcoe should be coordinated with the province and with agencies such as the International Joint Commission and the Great Lakes Fisheries Commission that are working to prevent introductions to the Great Lakes.

2.9 **Loss of Natural Areas and Habitats**

The following are recommended approaches to mitigate the loss and degradation of natural areas and habitats for terrestrial biodiversity and other natural values in the watershed. Protection of these features will also serve to reduce P loads, and contaminants and pathogens to the lake by trapping sediment and water and buffering atmospheric deposition. Clean water is the product of a healthy watershed.

Address information gaps:

- *Determine thresholds of permanent habitat conversion beyond which irreversible and negative effects on the lake ecosystem will occur. A moratorium on conversion is recommended until these have been determined at the watershed level.*
- *Connections need to be made between the natural heritage strategy, species needs and the watershed context, (i.e. Simcoe County and beyond) to identify what needs to be preserved and protected outside the watershed boundary.*
- *Complete an assessment of local species and their habitat requirements to develop appropriate habitat protection across and beyond the watershed.*
- *In the identification of natural areas for protection, include the consideration of functionality of the features in scoring their importance in the watershed.*
- *Develop comprehensive GIS databases for littoral and riparian zone features and the spatial distribution of aquatic and terrestrial species, including plants.*

Recommendation 35

Loss of Natural Areas and Habitats – Evaluate the proportional coverage of intact forested areas and thresholds of habitat conversion that are required to protect the ecological health of the lake and the resident biodiversity in its watershed. During the interim, to prevent further loss of naturalized areas, a minimum of a 40 % cover of high quality, intact habitat should be maintained for the watershed, as well as identifying priority areas and targets for re-naturalization

Recommendation 36

Loss of Natural Areas and Habitats – Reduce fragmentation through the protection and creation, where needed, of wildlife corridors and forest linkages within and beyond the watershed boundary.

- Although it has been influenced by human activity, particularly land use changes, for more than 200 years (Evans et al. 1996; LSEMS 2008), Lake Simcoe remains a valuable natural and recreational resource and an important source of drinking water. Over the past few decades in particular, the lake's watershed has been subjected to extensive alterations by agricultural and urban development activities, and exurban build-up (build-up beyond the suburbs).
- As the amount of forest habitat declines in an area, certain elements of biodiversity exhibit population declines with resultant changes to community structure, with edge-loving generalist species replacing "interior" species in fragmented landscapes. Larger, intact habitats will support more native species, particularly "interior species" that are vulnerable to the negative influences of edge environments between natural and artificial/converted habitats.
- Even among those species residing in similar habitats (e.g., wetlands or forests), their requirements can be highly variable with respect to the amount and/or quality of habitat necessary for their persistence (Fahrig 2002). Many area-sensitive or otherwise rare species have lower thresholds of tolerance for habitat conversion and will be among the first to disappear. There is no "one size fits all" metric that can be prescribed for the amount of natural habitat in a landscape that should be conserved. One recent literature review (ELI 2003) found the amount varied from 5-80%, with 75% of the studies reporting that at least 50% of the high-quality habitat (suitable for breeding and not acting as a "population sink" where deaths of individuals outpace births) must be retained, particularly for birds and invertebrates.
- The total amount of habitat conserved in a landscape is of even greater importance for conservation of resident biodiversity than the degree of fragmentation, until a threshold of ca. 30%, whereupon the spatial arrangement of habitat patches becomes the overriding factor in determining species persistence (Andren 1994).
- Loss of species and habitat degradation can also create conditions conducive to the entry of invasive species causing an overall decline in biological diversity.
- There is a need for large, contiguous and connected areas, avoiding habitat fragmentation. Core habitat and natural areas should remain large and protected from negative influences of land conversion, i.e., a minimum of 300 m buffer around natural areas will minimize edge effects on sensitive interior forest species (ELI 2003).
- In general, forested habitat guidelines for the sub-watersheds should be developed that serve to minimize the extent of fragmentation and habitat erosion for the most sensitive elements of biodiversity.

- As important as appropriate widths for riparian buffers are for conserving faunal communities (see recommendations #2 and #3), caution is merited for relying on these without proper consideration of the landscape context. For neotropical migrant bird communities, Rodewald and Bakermans (2006) provide evidence for the need to take into account the potential impacts of current and anticipated future land uses surrounding forest remnants. Those riparian zones adjacent to urban habitats are most vulnerable explaining over 90% of the variation in bird communities.
- Linkages between large, intact core habitats should be protected, restored and maintained, particularly along riparian areas (see recommendations #2 and #3).
- Riparian areas, in their position as transitional ecosystems between aquatic and terrestrial habitats, are often regional hotspots of diversity and richness, and function as connections between terrestrial habitats (National Research Council 2002).

Recommendation 37

Loss of Natural Areas and Habitats – Protect all wetlands within the watershed to maximize protection of water quantity and quality and buffer them from adjacent converted lands.

- As defined in the Ontario Wetland Evaluation System, wetlands are "land types that are commonly referred to as swamps, fens, mires, marshes, bogs, sloughs and peatlands. They occur intermittently across the landscape along lakes, rivers and streams, and in other areas where the water table is close to the surface. As areas where land and water join, wetlands provide unique and specialized habitats for a great variety of species that can live nowhere else. The survival of wetland helps to preserve ecological processes and functions that secure and protect the quality of the biosphere in which humans and other organisms together must dwell" (OWES, MNR 1993).
- Wetlands serve vital ecological functions, such as water purification, flood storage, sediment trapping, and wildlife habitat
- Existing wetlands should be buffered from adjacent converted areas by at least 300 m wherever possible.

Recommendation 38

Loss of Natural Areas and Habitats – Protect floodplains from development, including seasonal wetlands and forested valley lands.

- All floodplains within the watershed should be identified and mapped, and municipal official plan zoning schedules should identify these areas as hazardous lands for protection from development.
- Minimizing or eliminating floodplain development would alleviate flooding conflicts in the watershed and reduce the influx of P loads from impervious surfaces.

Recommendation 39

Loss of Natural Areas and Habitats – Expand the relevant protection policies in place within the Greenbelt and Oak Ridges Moraine Plans for naturalized areas to the entire watershed to help facilitate the protection of natural areas, the approvals of appropriate development, and the use of green technology.

- For example, the spatial extent of the Greenbelt Plan does not include areas in the north and the western portions of the watershed. Its protections should be extended to all areas in the watershed, with particular attention to those portions of the watershed where development pressure is high.

2.10 Water Extraction

Address information gaps:

- *Investigate re-use of wastewater to minimize outputs and inputs to the system.*
- *Quantify the use and extraction of water in the watershed for the various sectors, i.e., municipal, industrial, agriculture, bottling etc.*
- *Quantify the amount of water that can be used in a sustainable manner in each sub-watershed.*
- *Re-evaluate the permit-taking program to include permits for volumes of less than 50,000 L d^{-1} to control extraction.*

Recommendation 40

Water Extraction – Implement sustainable use of water in the Lake Simcoe watershed.

- Avoid subsidizing costs for water taking.
- Implement municipal by-laws to minimize residential water use.

Recommendation 41

Water Extraction – Implement a ban on new export or import of water into or out of the Lake Simcoe watershed until such time that a basin-wide strategy of sustainable water management is completed.

Recommendation 42

Water Extraction – Implement sustainable water resource extraction levels in each sub-watershed.

The SciAC identified preliminary information gaps to be addressed and made the following recommendations to mitigate the impact of the stressors acting on Lake Simcoe (Table 3):

Table 3 - Summary of SciAC Recommendations

General

1. Develop total P targets for the three Lake Simcoe basins and the sub-watersheds:
   a) Kempenfelt Bay – key deep water habitat for juvenile lake trout;
   b) Cook's Bay – excessive macrophyte growth;
   c) Main Basin – primary habitat for most native fish species;
   d) Sub-watersheds – refine the analysis of sub-watershed contributions of P from all sources and incorporate with revised lake and basin targets to update sub-watershed targets.
2. No new or expanded development or site alteration and mandatory vegetated buffer zones along the lake shoreline and all watercourses are recommended throughout the watershed as follows:
   a) within 100 m of undeveloped Lake Simcoe shoreline, and other shorelines in the watershed known to serve connectivity functions, coldwater or headwater streams, or other riparian zones requiring enhanced water quality protection,
   b) within 30 m along other parts of the Lake Simcoe shoreline and other intermittent or perennial water courses in the watershed,
   c) in those intensively developed areas (e.g. urban, agricultural and recreational) where a 30 m zone is not feasible, rehabilitate shorelines of the lake and its watershed to at least 15 m by restoring native vegetation where ever possible and avoiding the use of chemicals (e.g. fertilizers, pesticides),
   d) no new shoreline developments or shoreline activities on land or in the water that disrupt natural shoreline processes or that otherwise damage riparian or littoral zone habitats.
3. Provide incentives for the creation of larger buffer strips in sensitive areas to protect aquatic features and functions.

Sewage Treatment Plants

4. Limit total P loads discharged from all STPs to the current annual load i.e., no increases above current loads to the lake.
5. Integrate the best available technology during STP expansions to meet new total P loading limits and improve removal of other pollutants.
6. Implement an incentive program for under-shooting P caps.
7. Consider interim provincial regulations to ban phosphates in dishwasher detergents until the federal plan is in effect (currently proposed for 2010).
8. Monitor pharmaceutical contamination by collecting effluent samples from all STPs in the watershed to develop targets for the receiving waters, and enforce treatment changes to

Table 3 - Summary of SciAC Recommendations

meet targets.

9. Use the best commercially available technology and/or management strategies for all STP expansions and upgrades with the objective of removing pharmaceuticals altogether.
10. Investigate options for use of current effluents for other purposes, e.g., irrigation of sod farms, golf courses, etc. Move to zero effluent discharge from sewage treatment facilities and provide incentives for doing so.

Storm-water Sources

11. Decrease P loads from urban storm-water runoff below current levels.
12. Endorse green technology and smart growth management plans that encourage permeable development strategies and off-setting to reduce flow into storm-water control systems.
13. Set maximum impervious surface targets (% cover) for the watershed and sub-watersheds.
14. Storm-water management must include retrofitting or constructing new infrastructure, especially in areas where no storm-water facilities existed before.

Agriculture

15. Continue the implementation of good farming practices and best management practices in the watershed based on the local conditions of the land through the Nutrient Management Act and Environmental Farm Planning process to address concerns about nutrient and contaminant inputs and soil loss.
16. All farms (small and large) in the watershed should implement a nutrient management plan (NMP).
17. No new expansion or development of farms into existing natural areas.
18. Avoid application of nutrients on frozen or snow-covered ground.
19. Exclusion of livestock from all watercourses.
20. Implement erosion control incentives to encourage the participation of all farms in the watershed to minimize erosion of exposed soils (by wind and water) and P loading to the lake.
21. Monitor the impacts of the implementation of recommended best management practices on agricultural land to determine if particular sub-watersheds would need additional controls on the variety and spatial extent of agricultural uses, farm location, livestock density or farming intensification to meet the levels of P inputs that the lake can sustain.
22. Develop a voluntary certification program for green farming practices throughout the watershed (e.g., similar principles applied with the voluntary Environmental Farm Plan).
23. Develop best management practices for tile drains to minimize losses of nutrients, sediment and water.

Table 3 - Summary of SciAC Recommendations
Construction Sites
24. Review existing construction guidelines in Ontario to ensure their sufficiency to reduce the erosion losses of exposed soils off-site and overall P loads to the lake and its inflowing watercourses.
25. Implement and maintain wind erosion mitigating efforts at all construction sites to reduce P and sediment loads to the lake and its tributaries in order to minimize the impacts from atmospheric deposition, e.g., cover exposed soils, plant or erect wind breaks, and use non-toxic based dust suppressants.
26. Encourage all municipalities to adopt green building certification programs, such as the Leadership in Energy and Environmental Design (LEED) and Minnesota GreenStar Systems certification program.
Septic Systems
27. The ultimate objective is to provide new development and redevelopment incentives to phase out septic systems completely or to upgrade to on site sewage treatment systems that will completely eliminate P loading where applicable. In the interim, revitalize the Septic System Re-inspection Program and provide recommendations for upgrades.
28. Provide financial incentives to encourage property owners to upgrade systems and use best available technology (MOE approved).
29. Promote regular maintenance of septic systems through pump outs every 3 to 5 years for systems greater than 10 years of age to improve the efficiency of the system to minimize nutrient and pathogen loading to the lake.
Atmospheric Deposition
30. Implement the use of windbreaks and shelter belts in the watershed, including along the lake's shoreline.
31. Non-toxic dust suppression and soil stabilization are recommended at all active construction sites, aggregate mining, and unpaved roads.
32. Surface roughening, cover crops and conservation tillage systems are recommended for farmers to reduce wind erosion.
Introduced Species
33. Investigate, with the use of critical monitoring, how invasive species enter the system and their impacts on the lake and its watershed to determine future options for management.
34. Coordinate and implement measures (education and regulations) that prevent additional invasive species from entering the lake and watershed to meet the "no new invasive species" watershed target. Work with federal and provincial agencies such as the International Joint Commission, the Great Lakes Fisheries Commission and the Ontario-Canada Agreement (COA).

Table 3 - Summary of SciAC Recommendations
Loss of Natural Areas and Habitats
35. Evaluate the proportional coverage of intact forested areas and thresholds of habitat conversion that are required to protect the ecological health of the lake and the resident biodiversity in its watershed. During the interim, to prevent further loss of naturalized areas, a minimum of a 40% cover of high quality, intact habitat should be maintained for the watershed, as well as identifying priority areas and targets for re-naturalization.
36. Reduce fragmentation through the protection and creation, where needed, of wildlife corridors and forest linkages within and beyond the watershed boundary.
37. Protect all wetlands within the watershed to maximize protection of water quantity and quality and buffer them from adjacent converted lands.
38. Protect floodplains from development, including seasonal wetlands and forested valley lands.
39. Expand the relevant protection policies in place within the Greenbelt and Oak Ridges Moraine Plans for naturalized areas to the entire watershed to help facilitate the protection of natural areas, the approvals of appropriate development, and the use of green technology.
Water Extraction
40. Implement the sustainable use of water in the Lake Simcoe watershed.
41. Implement a ban on new export or import of water into or out of the Lake Simcoe watershed until such time that a basin-wide strategy for sustainable water management is completed.
42. Implement sustainable water resource extraction levels in each sub-watershed.

Q.11 – Is it necessary to identify areas of special concern for restoration and protection within the lake and its watershed (such as nearshore areas, bays, sub-watersheds, certain terrestrial features, riparian areas, wetlands, or headwater streams)?

Identification, protection and restoration of specific areas within the watershed that need focused management efforts are among the key steps needed to improve the long-term health of the lake.

Areas that are of particular concern deserving special attention include those that have been degraded or are at particular risk due to current or future threats. These areas are identified because they require specific attention to either eliminate a past problem (e.g., contaminated soils) or prevent a future impact (e.g., loss of a wetland) and include other areas where great uncertainty about future consequences exists (e.g., effects of pharmaceuticals and drugs).

There are three key categories of areas of special concern that must be addressed on Lake Simcoe:

- Areas that are degraded or impaired
- Areas of high ecological value or sensitivity
- Areas of emerging concern

1. Areas that are Degraded or Impaired

Areas that are degraded or impaired, with respect to downstream water quality in particular, include perturbed or contaminated areas that affect the immediate or adjacent lands and waters. The following areas in the Lake Simcoe watershed were identified and require further investigation and remediation:

a. Polders – There are 4 polders being cultivated (Bradford, Keswick, Colbar, Holland) that require polder-specific approaches to reducing P and other stressors on downstream water quality. Generally, there is a need to implement intensive remediation to treat runoff; assess the feasibility of additional treatment measures to reduce P, sediment and contaminants from runoff and export (e.g., treatment of pumped out waters); provide practices for the disposal of sediment removed from the canal; and to collect more information on soils.

b. Cook's Bay – Cooks Bay has extensive warm-water habitat that is threatened by excessive macrophyte growth and significant P loading from the Holland River.

c. Other nearshore areas – experience excessive macrophyte growth and elevated levels of bacteria causing beach closures.

d. East and West Holland River – high loads of nutrients and metals; Tannery Creek is a high priority.

e. Urban creeks that need rehabilitation.

f. Harvested peatlands that require restoration.

g. Maskinonge River – base flow must be maintained and protected from water extraction.

2. Areas of High Ecological or Socio-Cultural Value or Sensitivity

Areas that are of high ecological or socio-cultural value or sensitivity are identified as a result of the existence of a special natural or cultural feature that needs protection from loss or alteration. The following are areas of high ecological, cultural or aesthetic value or sensitivity and require investigation and immediate protection, however, it should be noted that not all have been specifically identified, and most are listed here as classes of areas. Accordingly, some work will be needed to locate and map these as part of the Protection Plan.

Ecological

a. All remaining wetlands (provincially, regionally and locally significant).

b. Cold-water and head water streams.

c. Kempenfelt Bay's special attribute of providing prime cold-water habitat for juvenile lake trout and associated species.
d. Shorelines/riparian areas as discussed above.
e. Spawning habitats of sensitive cold-water fish species.
f. Sources of ground water (aquifers).
g. Wildlife travel corridors.
h. River valleys.
i. Intact forested lands.
j. Hypolimnetic waters.
k. Littoral zone fish habitats
l. Rare ecological communities and significant geological features (e.g., alvars, hibernacula – areas chosen by species for hibernation).

Socio-Cultural

a. Aboriginal areas and values (e.g. narrows, islands, burial grounds, sacred sites).
b. Archaeological and historic sites (e.g. Atherley Narrows, one of the earliest fishing weirs in North America).
c. The aesthetic value of natural landscapes e.g. landscapes, lakescapes and viewscapes including the sights and scents of healthy streams, lakeshores, wetlands, river valleys and forests.
d. Protected natural areas.
e. Public beaches.
f. Sustainable agricultural areas (e.g. farms and local food production).

3. Emerging Concerns

Emerging concerns are threats or pressures that are occurring today or are likely to occur or escalate in the future. In some cases there is great uncertainty about future consequences (e.g. the effects of pharmaceuticals on aquatic organisms). The following are emerging areas that require investigation:

a. Development in areas of current and projected urban growth.
b. Future urban development and loss of agricultural lands, natural shorelines, and natural areas and features (e.g. wetlands, valley lands).
c. New invasive species introductions.
d. Construction practices in areas under development and associated sediment and nutrient loading.
e. Areas of contaminated sediments.
f. Climate change.
g. Pharmaceuticals.
h. Emerging toxic contaminants.

i. Bogs and fens require immediate protection from soil and peat extraction.

New management approaches are required to address and deal with all of these areas of concern. In some cases, research and additional information is required but in most cases the issues are well defined spatially and mechanisms of impact are reasonably well understood. In some cases environmental or technical solutions are available but in others new solutions must be developed. However, these problems are usually complex and involve multiple activities and sectors, and regulatory tools are not presently available to manage several key issues. A policy scan is required by the partner Ministries to identify policy areas and legislative opportunities for addressing these issues.

Report 3 – References

Aherne, J., M.N. Futter and P.J. Dillon. 2007. The impacts of future climate change and sulphur emission reductions on acidification recovery at Plastic Lake, Ontario. Hydrol. Earth Sys. Sci. 4: 3027-3054.

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: A review. Oikos 7:355-366.

Austen, MJW, Francis, CM, Burke, DM, and Bradstreet, MSW. 2001. Landscape context and fragmentation effects on forest birds in southern Ontario. Condor 103(4):701-714.

Arnold, L.W., Jr. and C.J. Gibbons. 1996. Impervious surface coverage: the emergence of a key environmental indicator. J. Amer. Planning Assoc. 62:243-258.

Booth, D.B., and C.R. Jackson. 1997. Urbanization of aquatic ecosystems: degradation, thresholds, storm-water detection, and the limits of mitigation. J. Amer. Water Resources Assoc. 33:1077-1090.

Barton, D.R. 1996. The use of Percent Model Affinity to assess the effects of agriculture on benthic invertebrate communities in headwater streams of southern Ontario, Canada. Freshwater Biology 36:397-410.

Barton, D.R., Taylor, W.D. & Biette, R.M. 1985. The relationship between riparian buffer strips and salmonid habitat in southern Ontario streams. N. Am. J. Fish. Manag. 5: 364-378.

Burbrink, F.T., Phillips, C. A., and Heske, E. J. 1998. A riparian zone in southern Illinois as a potential dispersal corridor for reptiles and amphibians. Biological Conservation 86:107-115.

Castelle, A.J., A.W. Johnson & C. Conolly.1994. Wetland and stream buffer size requirements - a review. J. Environ. Qual. 23: 878-882.

Eisenhauer N, Partsch S, Parkinson D, and Scheu S. 2007. Invasion of a deciduous forest by earthworms: Changes in soil chemistry, microflora, microarthropods and vegetation. Soil Biology & Biochemistry 39(5):1099-1110.

Environmental Law Institute (ELI). 2003. Conservation Thresholds for Land Use Planners. Environmental Law Institute, Washington, DC.

Evans, D. O., J. J. Houston, and G. N. Meredith. 1988. Report on the status of the Lake Simcoe whitefish, Coregonus clupeaformis, in Canada. Can. Field Nat. 102:103-113.

Evans, D. O., and C.H. Olver. 1995. Introduction of lake trout, Salvelinus namaycush, to inland lakes of Ontario, Canada: factors contributing to successful colonization. J. Great Lakes Res. (Supplement 1):30-53.

Evans, D. O., K. H. Nicholls, Y. C. Allen, and M. J. McMurtry. 1996. Historical land use, phosphorus loading and loss of fish habitat in Lake Simcoe, Canada. Can. J. Fish. Aquatic Sci. 53 (Suppl. 1): 194-218.

Evans, D.O. 2007. Effects of hypoxia on scope-for-activity and power capacity of lake trout (Salvelinus namaycush). Can. J. Fish. Aquatic Sci. 64:1-17.

Evans, D.O. 2008. Thermal niche and dissolved oxygen requirements of lake trout with reference to fishery yields in changing environments. Proceedings 2nd Lake Trout Symp. 2005. Fisheries and Oceans Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2778:73-83.

Fahrig, L. 2001. How much habitat is enough? Biological Conservation 100(1):65-74.

Fahrig, L. 2002. Effect of habitat fragmentation on the extinction threshold: A synthesis. Ecological Applications 12:346-353.

Frimpong, E.A., T.M. Sutton, K.J. Lim, P.J. Hrodey, B.A. Engel, T.P. Simon, J.G. Lee & D.C. Le Master. 2005. Determination of optimal riparian forest buffer dimensions for stream biota-landscape association models using multimetric and multivariate responses.Can. J. Fish. Aquat. Sci. 62: 1-6.

Gibbs, J.P. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal Of Wildlife Management 62(2):584-589.

Gibson, E.S. and F.E.J. Fry. 1954. The performance of the lake trout, Salvelinus namaycush, at various levels of temperature and oxygen pressure. Can. J. Zool. 32:252-260.

Guildford S.J., D.C.G. Muir, M. Houde, M.S. Evans, K.A. Kidd, D.M. Whittle, K. Drouillard, X. Wang, M.R. Anderson, C.R. Bronte, D.S. DeVault, D. Haffner , J. Payne and H.J. Kling. Influence of geographic factors and possible implications of climate warming for PCB concentrations in lake trout (Salvelinus namaycush). Submitted to Environmental Science and Technology May 2008

Hanowski, J.M., Wolter, P.T., & Niemi, G.J.2002. Effects of prescriptive riparian buffers on landscape characteristics in northern Minnesota, USA. J. Amer. Water Res. Assoc. 38: 633-639

Houde M., D.C.G. Muir, K.A. Kidd, S.J. Guildford, K. Drouillard, M.S. Evans, X. Wang, D.M. Whittle, D. Haffner , and H.J. Kling. 2008. Influence of lake characteristics on the biomagnifications of persistent organic pollutants in lake trout food webs. Environmental Toxicology and Chemistry 27: in press.

Johnson, M. G., and K. H. Nicholls. 1989. Temporal and spatial variability in sediment and phosphorus loads to Lake Simcoe, Ontario. J. Great. Lakes Res., 15:265-282.

Kilgo, J. C., Sargent, R. A., Chapman, B. R., and Miller, K. V. (1998). Effect of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. Journal of Wildlife Management 62:72-83.

King, J.R., B.J. Shuter, and A.P. Zimmerman. 1997. The response of the thermal stratification of Soth Bay (Lake Huron) to climatic variability. Can. J. Fish. Aquat. Sci. 54:1873-1882.

Lee, M, Fahrig L, Freemark K, and Currie DJ. 2002. Oikos. 96(1):110-118.

Lienesch, P.W., M.E. McDonald, A.E. Hershey, W.J. O'Brien and N.D. Bettez. 2005. Effects of a whole-lake, experimental fertilization on lake trout in an oligotrophic arctic lake. Hydrobiologia 548:51-66.

Loftus, K.H., and H.A. Reiger. 1972. Introduction to the proceedings of the 1971 Symposium on Salmonid Communities in Oligotrophic Lakes, Journal of Fisheries Research Board of Canada. 29:613-616.

LSEMS. 2003. State of the Lake Simcoe watershed. Lake Simcoe Region Conservation Authority, Newmarket, ON.

LSEMS. 2008. Lake Simcoe basin wide report. Lake Simcoe Region Conservation Authority, Newmarket, ON.

LSRCA. 2007. Lake Simcoe basin storm-water management and retrofit opportunities. Lake Simcoe Region Conservation Authority, Newmarket, ON.

Mason J, Moorman C, Hess G, Sinclair K. 2007. Designing suburban greenways to provide habitat for forest-breeding birds. Landscape And Urban Planning 80:153-164.

Mitchell, F. (1996). Vegetated buffers for wetlands and surface waters: Guidance for New Hampshire municipalities. Wetlands Journal 8:4-8.

Molot, L.A., G. Li, D.L. Findlay and S.B. Watson (2008) Iron regulation of bloom forming cyanobacteria abundance. Presentation at the 51st Annual Conference on Great Lakes Research.

National Research Council (NRC). 2002. Riparian Areas: Functions and Strategies for Management. National Academy Press, Washington, DC.

Nicholls, K.H. 1997. A limnological basis for a Lake Simcoe phosphorus loading objective. Lake and Reservoir Management 13:189-198.

Ontario Ministry of Natural Resources, 2006. Inland Ontario Lakes Designated for Lake Trout Management. Queen's Printer of Ontario.

Pringle, C. 2001. Hydrologic connectivity and the management of biologicalreserves: A global perspective. Ecological Applications 11(4):981-998.

Ray, J.C. 2005. Sprawl and highly mobile or wide-ranging species. Pp 181-205 In: Nature in Fragments: Urban Sprawl's Effects on Biodiversity (E. A. Johnson and M.W. Klemens, eds.), Columbia University Press.

Rodewald, AD and Bakerman, MH. 2006. What is the appropriate paradigm for riparian forest conservation? Biological Conservation 128(2):193-200.

Sellers, T. J., B. R. Parker, D. W. Schindler and W. M. Tonn. 1998. Pelagic distribution of lake trout (Salvelinus namaycush) in small Canadian Shield lakes with respect to temperature, dissolved oxygen and light. Can. J. Fish. Aquat. Sci. 55:170-179.
Semlitsch, R.D. 2000. Principles for management of aquatic-breeding amphibians Journal of Wildlife Management, 64(3):615-631.

Spaling, H. 1995. Analyzing cumulative environmental impacts of agricultural land drainage in southern Ontario, Canada. Agriculture, Ecosystems and Environment 53:279-292.

Sparovek, G., S.B.L. Rauieri, A. Gassner, I.C. DeMaria, E. Schnug, R.F. dosSantos & A. Joubert.2002. A conceptual framework for the definition of the optimal width of riparian forests. Agricul. Ecosyst. Environ. 90(2): 169-175.

Stone, M. and B.G. Krishnappan. 1997. Transport characteristics of tile-drain sediments from an agricultural watershed. Water, Air and Soil Pollution 99:89-103.

Stone, M. and B.G. Krishnappan. 2002. The effect of irrigation on tile sediment transport in a headwater stream. Water Research 36:3439-3448.

Vander Zanden, M.J., J.M. Casselman and J.B. Rassmussen. 1999. Stable isotope evidence for the food web consequences of species invasions in lakes. Nature 401:464-467.

Wobeser, G. 2002. New and emerging diseases — The wildlife interface. Canadian Veterinary Journal. 43(10):798.

U.S. Department of Agriculture. 2002. Wind erosion, part 502. In National Agronomy Manual. Washington, D.C.

Zhang, C.L., X.Y. Zou, J.R. Gong, L.Y. Liu and Y.Z. Liu. 2004. Aerodynamic roughness of cultivated soil and its influences on soil erosion by wind in a wind tunnel. Soil and Tillage Research 75:53-59.

Q. 12 – What approach should be used to establish and maintain up-to-date objectives and targets for the lake and its watershed to support the proposed Lake Simcoe Protection Plan?

The first approach to establish and maintain up-to-date objectives and targets in the Lake Simcoe Protection Plan is to develop a watershed-wide monitoring strategy that includes all partners and comprehensively addresses the eight identified stressors and indicators. To accomplish this, existing monitoring program must be supported and new monitoring programs added. Monitoring programs are critical for evaluating the efficacy of management actions taken to mitigate these stressors, and for the early detection of new threats.

An excellent means of ensuring that management and monitoring are integrated and mutually supportive is the use of the adaptive management approach. Adaptive management is a structured process for continually improving management practices by testing selected options that are considered most likely to achieve specified management objectives, learning from their outcomes and making adjustments as required. This process combines analysis and selection of management options based on the best available science with monitoring to track system responses, and uses new monitoring and research information to make adjustments to continually improve the effectiveness of management efforts.

...adaptive management ensures that management and monitoring are integrated and mutually supportive...

Past management approaches have focused on the monitoring of P loading to the lake from various sources to determine the effects on aquatic resources, with particular reference to the cold-water fish community and water quality. In recent years, monitoring efforts have expanded to include atmospheric sources of P as well as the implications of invasive species and plant growth to the cycling of P in the lake. New approaches must go beyond the lake-specific focus and include the study of the entire drainage basin to measure and link the effects of the loss of terrestrial components and changes in land use to changes in the lake environment.

Future Monitoring Efforts in the Lake Simcoe Basin

Monitoring is the cornerstone of a science-based adaptive management approach. The collection of data over the past few decades through the efforts of the Lake Simcoe Environmental Management Strategy partnership has enabled scientists and managers to describe significant trends in some parameters over time, both in the aquatic and the terrestrial components of the ecosystem. Without these baseline data, defining, managing and protecting the ecological state of the lake would not be possible. Some trends, however, have not been mapped consistently over time or at the scales required to constitute an adequate information base. Consequently, the monitoring approach employed in the future

must include a component of information gathering for the purposes of mapping and regular reporting of key indicators corresponding with stressors.

Long-term data enables scientists, managers, and planners to understand human-induced or natural variations, to assess long and short term trends, and to advance our understanding of ecological processes. The continuous monitoring, evaluation and reporting of indicators and trends promotes consistent program application (reducing the uncertainties in trend interpretation), provides an ongoing awareness of the status of the health of the ecosystem, and verifies and helps update management practices to meet emerging issues. Establishing monitoring priorities to address information gaps identified in the existing programs will also help identify the funding and resources needed to enable adaptive monitoring to address uncertainties and unforeseen changes in the environment (Cairns et al. 1993 and Rapport et al. 1998).

A robust monitoring program is an essential component of the Lake Simcoe Protection Plan. To develop a comprehensive watershed-wide monitoring strategy the following general approach must be applied:

1. **Address the <u>magnitude of all 8 identified stressors</u>** that impact the ecological health of Lake Simcoe**.** Past monitoring efforts have focused on key aquatic stressors and these efforts must now be expanded to deal with all 8 stressors in a comprehensive way. Stressors do not act independently; they affect one another, and may also have interactive effects on the lake and watershed. It is also important that we improve understanding of the mechanisms of action of all eight stressors to expand our knowledge base so that we can anticipate and become aware of emerging issues, and can put appropriate management approaches in place in a timely and effective manner.

2. **Address the <u>key indicators of ecosystem health</u>** that relate to the action of all 8 stressors to ensure that management targets are being met. Observations of major changes in the basin must be associated with key measurable indicators that are monitored over time to help scientists and managers understand and interpret ecosystem trends. Monitoring indicators tells us about the immediate and long term health of the lake and its watershed and identifies impacts (environmental, social and economic), helping us to better select the appropriate management and stewardship activities.

3. **Address the <u>key processes</u>** such as nutrient cycling, nutrient transport, carbon cycling, food web dynamics, and species interactions that maintain the ecological health of Lake Simcoe and its watershed and together define the state of the ecosystem. Monitoring and developing an improved understanding of these

Stressors

- *Nutrients*
- *Pollutants*
- *Pathogens*
- *Invasive species*
- *Climate change*
- *Loss of watershed integrity*
- *Water extraction*
- *Other human pressures*

Key Indicators include…

- *Status of cold water fish community*
- *Status of terrestrial and other aquatic indicator species*
- *Deep water dissolved oxygen*
- *Total P in water*
- *Pollutant Concentrations (water, sediment, tissue)*
- *Beach closures*
- *Composition of biotic communities*
- *Invasive species*
- *Changes in lake temperature and duration of ice cover*

Key Processes

- *Nutrient Cycling*
- *Nutrient Transport*
- *Carbon Cycling*
- *Lake Metabolism*
- *Food Web Dynamics*
- *Species Interactions*

essential physical, chemical and biological processes will improve our ability to understand the effects of land-use changes and human population growth on the lake, and to develop appropriate and effective management procedures to reduce their impacts.

Requirements for Monitoring

The following are the requirements to be considered when developing a monitoring program:

1. <u>Design a comprehensive and adaptable, monitoring program</u> with effective statistical power to enable detection and understanding of changes in the indicators. This requires a full set of parameters to be measured at an appropriate number of stations and sampling frequency and over all time frames.

2. <u>Provide sustained and consistent funding</u> – by identifying the full funding needs to meet the desired scope of the monitoring program.

3. <u>Link monitoring to the implementation efforts</u> – by using monitoring results to identify priority areas for implementation of management actions.

4. <u>Where possible, improve existing monitoring programs - by expanding the number of stations and increasing sampling frequency</u> to address critical information needs, e.g., increasing the number of monitoring stations in the tributaries and the lake as well as the atmospheric deposition monitoring sites.

5. <u>Establish new research or monitoring programs to fill information gaps including:</u>
    - P cycling and storage within Lake Simcoe and its tributaries;
    - Bioavailability of soil P;
    - Spatial and temporal identification of areas contributing runoff (sediments and nutrients, particularly P) to surface waters;
    - Evaluation of the dimensions (widths and lengths) required for effective buffer zones based on local soils, slopes and land uses;
    - Assess the risk of higher density development associated with municipal servicing versus septic system use;
    - Assessment of nutrient and pathogen contamination from septic systems;
    - Assessment of new technological opportunities to reduce P loads from sewage treatment plants, construction sites (atmospheric and storm-water), septic systems and storm-water;
    - Assessment of the sources and impacts of atmospheric deposition from various activities/land uses;
    - The effects of degraded air quality on native species and their habitats, as well as the impacts on human health;
    - Monitor on-going land use changes and landscape pattern of natural habitats in the watershed through the use of high resolution air photos or satellite imagery and permitting records;

- Selected indicator species (or groups) representative of intact forest blocks (e.g., interior bird species) and wetlands (amphibians and birds) and wide-ranging species;
- Generalist/edge species (e.g., cowbirds, crows, blue jays, raccoons, feral cats, etc.);
- Ecological condition of principal intact forest blocks and wetlands;
- Selected wildlife/fish pathogens;
- Impacts of invasive species (zebra mussel etc.) on P cycling and macrophyte growth;
- Climate change effects on ecological processes and functions; and
- Presence, trends and distribution of new trace contaminants (e.g., pharmaceuticals).

6. Apply an adaptive management approach, requiring:
   - Ability to respond to unforeseen changes and to add new parameters and/or sites, new indicators and new technology as necessary;
   - Monitoring, data analysis, evaluation and timely reporting to decision-makers and the public;
   - Mapping of relevant indicators and mechanism to create maps
   - Engaging the community with science-based, user-friendly, communication products (websites, workshops, etc);
   - Real time alerts about some of the indicators, e.g., beach closures and invasive species, and provision of advice on what to do (based on management strategies);
   - Creating a governance structure that links community-based initiatives to avoid duplication, encourage synergies, and maximize resources and learning;
   - The commitment to adjust course in a timely manner when new information provides evidence for the need to shift, add to, or remove management actions outlined in the plan.

7. Develop a risk assessment tool for cost-effective management and monitoring
   - Conduct modelling studies (discreet choice, preferences, trade offs) to assess the public's priorities and willingness to act, pay etc.;
   - Invest in an assessment of the ecological carrying capacity of the watershed to inform thresholds of development pressure that if exceeded will likely lead to ecological change.

8. Ensure all monitoring programs are integrated – to identify aquatic trends in the three basins of the lake and all of the sub-watersheds, and to identify terrestrial trends within and beyond the watershed boundary. Integration could be improved by:
   a. Coordinating monitoring between agencies and experts
   b. Identifying roles and responsibilities for gathering and sharing data.

c. Providing access to all data and encouraging rapid reporting to maximize responsiveness.
d. Provision of adequate funding to support monitoring, science and reporting activities.

9. Consider additional approaches such as:
    a. Hypothesis of effects models – a stressor-specific conceptual model to organize and synthesize scientific knowledge and identify critical hypotheses, anticipate potential outcomes when stressor and response indicators change, and evaluate management options.
    b. Science-based, integrated watershed management models.
    c. Annual reporting, where possible, of key indicator trends.
    d. More frequent real time web-based reporting of some parameters
    e. A required effectiveness monitoring reporting cycle of 3-5 years, including a mechanism to change direction immediately if new information calls for it.

Applying an Ecological Management Model

The foundation of managing environmental health is a sound knowledge of current conditions. Monitoring ecological health indicators and identifying those stressors that are impacting the health of the system is essential for establishing environmental goals, identifying emerging issues, filling information gaps, refining indicators of healthy conditions, and setting new ecosystem objectives. If environmental conditions are threatened by a new stressor, its impact on the ecosystem must be evaluated. Once the mode of action of the stressor is understood, regulatory or remedial options must be developed and evaluated. Subsequently, the preferred management approach is implemented and monitored for compliance and effectiveness. Given the simplicity and flexible nature of this conceptual framework, it is proposed as an optimal model for adaptive environmental protection and management.

The ecological management model (following page) illustrates the cyclical and iterative nature of adaptive management – a learning approach which allows for corrective measures to manage systems on an ongoing basis, based on a process of implementation of a management strategy, monitoring, reporting, evaluation, re-assessment and adjustment. This model stresses the importance of monitoring the ecosystem while at the same time assessing society goals and gauging the response of the society to the selected management approaches through mechanisms such as attitude surveys or other public engagement models.

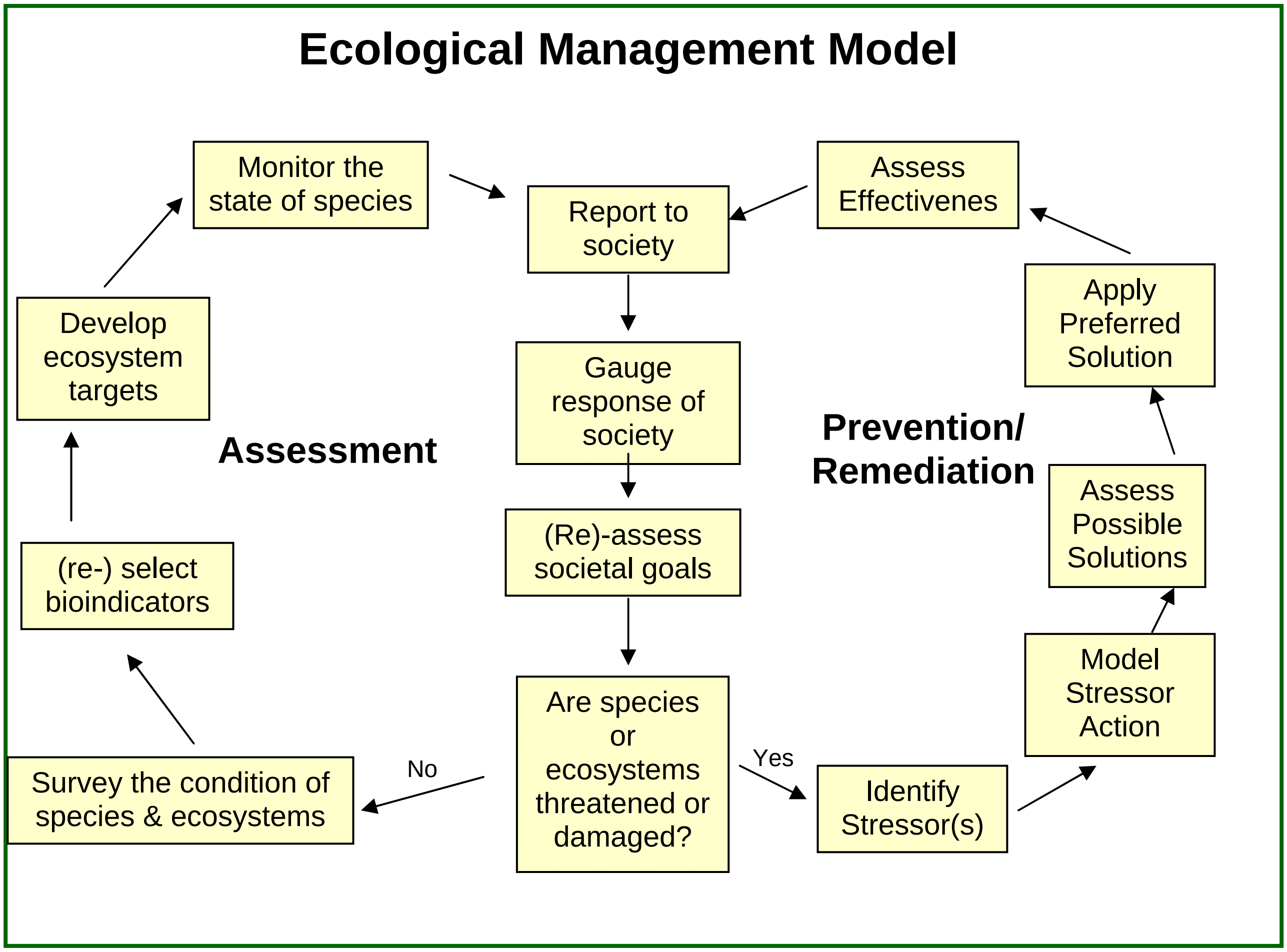


Figure 4 - Ecological Management Model

Current Monitoring in the Lake Simcoe Basin

Monitoring is an essential component of the current efforts to protect the health of Lake Simcoe and its watershed. The LSEMS partners are currently monitoring the health of the lake and its watershed to develop an understanding of the issues affecting the lake and to establish management strategies and recommendations for its protection and restoration (LSRCA Watershed Report Card 2008). These monitoring programs constitute a major contribution towards the current understanding of the changing state of the lake and the impact of stressors on it and represent a critical foundation for the enhanced monitoring program proposed in this report. However, the need for additional monitoring to address many of the stressors including the indicators that quantify their effects is great.

The following are examples of monitoring programs that are currently in place and should continue to form part of an expanded monitoring program:

Water Quality Monitoring – has been conducted at sampling stations in all sectors of Lake Simcoe since the early 1980s by the Ontario Ministry of the Environment. The Water Monitoring Section of MOE conducts long term, open-lake water quality (chemistry and

biology) monitoring. Water samples are collected from 8 lake stations and 3 Holland River stations every 2 weeks from May to October. Water samples are obtained year-round on a weekly basis from 3 drinking water intake stations. Samples are analyzed at the MOE labs (water chemistry) and through an external contractor (phytoplankton).

Parameters monitored include:

- Total P
- Organic nitrogen, nitrate and ammonia
- Cations (sodium, potassium, magnesium, calcium)
- Anions (sulphate, chloride)
- Metals (for lake stations)
- pH
- Water clarity (Secchi depth)
- Dissolved oxygen
- Chlorophyll
- Phytoplankton
- Zooplankton

Lake Simcoe Fish Populations – index netting and creel survey monitoring have been conducted annually since the 1960's. The Lake Simcoe Fisheries Assessment Unit of the Ministry of Natural Resources (LSFAU) conducts long-term monitoring of Lake Simcoe fish populations and of factors that affect fish populations including fishing, habitat loss, water quality, species introductions, and water levels. A small amount of stream/river monitoring also occurs (e.g. walleye in the Talbot River, lake whitefish in rivers). The following lists the types of information collected:

- Water level and temperature
- Summer and winter, yellow perch and smelt catch, fishing effort, catch and harvest sampling
- Lake trout and lake whitefish sampling, including stocked fish
- Fish diet
- Nearshore community index netting
- Fall index trap netting (lake trout and lake whitefish)
- contaminants in sport fish
- Occurrence and distribution of invasive species
- Fish habitat mapping of littoral zone areas
- Monitoring of other species (crayfish, clams, cormorants)

Lake Simcoe Sport Fish Contaminant Monitoring Program – sport fish are analyzed for contaminants on a regular basis. Fish collections are conducted by the LSFAU. Consumption advisories are published in the Guide to Eating Ontario Sport Fish. The most important species with respect to human consumption (e.g. lake trout, lake whitefish, smallmouth bass) are analyzed every three to five years. Other species are analyzed once every ten years. All species are analyzed for mercury; selected species are analyzed for organic pollutants including PCBs, organochlorine pesticides, dioxins and furans.

Nutrient Load Monitoring Program (MOE, LSRCA) - is conducted as part of the MOE's program to determine annual nutrient loads to the lake from non-point sources in the watershed. Flow data provided by the Water Survey of Canada (Environment Canada) are an essential component of the nutrient load calculation. Sampling began in the 1990s, and is conducted on the major sub-watersheds of the lake (currently at 18 stations). A private contractor collects samples for chemical analysis every two weeks; additional sampling is conducted during storm and snowmelt events. Samples are analyzed at the MOE laboratory.

Parameters monitored are:

- Flow rate (sites operated by the LSRCA and the Water Survey of Canada)
- Total P
- Organic nitrogen, nitrate and ammonia
- Chloride
- Water temperature

Provincial Water Quality Monitoring Network (MOE, LSRCA) – sampling is conducted as part of the Provincial Water Quality Monitoring Network (PWQMN) which provides measurement and assessment of water quality in rivers and streams throughout Ontario. Twelve stations in the Lake Simcoe watershed are currently being monitored. Samples are collected monthly by LSRCA staff and are analyzed at the MOE lab.

Parameters monitored include:

- Total P, phosphate
- Nitrite, nitrate, ammonia + ammonium, and total Kjeldahl nitrogen
- Cations (calcium, magnesium, hardness)
- Anions (chloride, sulphate)
- Metals
- pH, alkalinity, conductivity
- Suspended solids
- Water temperature

Biomonitoring (LSRCA, MOE) – of fish populations is undertaken at river and stream sites throughout the Lake Simcoe watershed. Fish are captured by electro-fishing stream reaches using standard protocols. The species present as well as the condition of the fish, are recorded and used to calculate an Index of Biotic Integrity (IBI) for the sites. Benthic macroinvertebrates are also sampled at selected river and stream stations throughout the watershed using the Ontario Benthos Biomonitoring Network protocol.

Provincial Groundwater Monitoring Network (LSRCA, MOE) – is conducted as part of the Provincial Groundwater Monitoring Network (PGMN) Program designed to monitor ambient groundwater conditions and is implemented through a MOE and LSRCA partnership. The Program began in 2000 and currently includes 14 wells throughout the Lake Simcoe watershed; 12 wells out of 14 provide information about groundwater chemistry and water levels for overburden aquifers and 2 wells provide the same information for bedrock aquifers. These wells, which are not used as water supplies, are used to monitor groundwater conditions including nutrients, metals and major ions. Information generated

through the PGMN Program provides important baseline data for the development, implementation and assessment of water management programs and activities such as Lake Simcoe Research Initiatives.

Flood Forecasting and Warning Network (LSRCA) – records water levels for member municipalities. Stations at Lovers Creek (1), Tannery Creek (4), Black River at Baldwin (8) and Beaver River (11) are operated and maintained by the LSRCA. Stations at Schomberg (3), Holland Landing (6) and Udora (10) are maintained by Environment Canada and the LSRCA downloads information from these sites. Rain gauges at the LSRCA office in Newmarket and at the Beaver River Station, accessed directly or through telemetry, are also part of the flood forecasting network and are operated by the LSRCA. In addition to flood forecasting, the water quantity data collected is used to help estimate P loading (when combined with water chemistry sampling).

Land Use Characterization and Change Monitoring (LSRCA / MNR) – monitors changes in land use over time to identify the direction and extent of changes in a specific feature or a land use type. For example urban areas are monitored not only for population growth over time but also associated features relating to storm-water runoff and the area served by municipal versus private sewage systems. Some of the other types of land uses that are monitored include: agricultural area, forested area, wetlands, open green space and rural development. The resulting information is used by the LSEMS partners to estimate total P loads to Lake Simcoe as well as supporting a number of other initiatives, such as the development and testing of best management practices.

Best Management Practices Assessment (LSRCA) – monitoring and assessment of best management practices that occur in the urban and rural areas of the watershed. Essentially, this relates to effectiveness monitoring. Current examples include performance monitoring of storm-water management facilities, and monitoring of a number of environmental projects completed across the watershed. This includes projects such as stream/livestock fencing, acres of trees planted, manure/milkhouse waste reduction and meters of erosion protected streambank. This information can be used to model the amount of P reduction achieved by these projects during any given time period or be used to monitor land use change.

Atmospheric Deposition Monitoring (MOE/LSRCA) – is conducted as part of the MOE's program to calculate atmospheric nutrient loads to Lake Simcoe. Monitoring of atmospheric deposition of nutrients began in 1995 and is now conducted at 6 locations around the lake. Bulk (all stations) and wet-only (2 stations) collectors are used that collect both wet and dry deposition. Samples are collected every week (depending on precipitation depth) by LSRCA staff, and are analyzed at MOE labs.

Parameters that are monitored include:

- total P;
- organic nitrogen, ammonia, nitrate;
- pH;
- cations.

Meteorological Monitoring (MOE / LSRCA) – two meteorological stations (Scanlon and Ramara) measure depth of precipitation, wind speed and direction, relative humidity, temperature, vapour pressure, and global radiation. In addition, the LSRCA operates 8 rain gauges (6 year-round and 2 seasonal) and 4 air temperature probes in other parts of the watershed.

Report 4 – References

Cairns, J.Jr., P.V. McCormick and B.R. Niederlehner. 1993. A proposed framework for developing indicators of ecosystem health. Hydrobiologia 263: 1-44.

Rapport, D.J., R. Costanza and A.J. McMichael. 1998. Assessing ecosystem health. Trends in Ecology and Evolution 13: 397-402.

Acronyms

CSeQG	Canadian Sediment Quality Guidelines
CWQG	Canadian Water Quality Guidelines
DDd	Dichlorodiphenyl dichlorothane
DDE	Dichlorodiphenyl dichloroethylene
DDT	Dichloro-Diphenyl-Trichloroethane
DO	Dissolved Oxygen
km^2	Kilometres Squared
L/day	Litres Per Day
LSEMS	Lake Simcoe Environmental Management Strategy
LSRCA	Lake Simcoe Region Conservation Authority
mean ± S.D.	Mean (+ or -) the Standard Deviation around the mean
mg/L	Milligrams per Litre
MOE	Ministry of the Environment
MNR	Ministry of Natural Resources
NH_3	Ammonia
N	Nitrogen
O_2	Oxygen
P	Phosphorus
PAHs	Polynuclear or Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated biphenyl
PHCs	Petroleum Hydrocarbons
PPM	Parts Per Million
PSQG	Provincial Sediment Quality Guideline
PWQO	Provincial Water Quality Objectives
SciAC	Science Advisory Committee
STP	Sewage Treatment Plants
TP	Total Phosphorus
t/y	Metric tonnes per year
µg/L	Micrograms per Litre
VHS	Viral Hemorrhagic Septicemia
WPCP	Water Pollution Control Plant